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**FM 5-34**

**ENGINEER FIELD DATA**



## ENGINEER FIELD DATA

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This manual supersedes FM 5-34, 12 December 1969, with all changes.



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# INTRODUCTION

## Section I. PURPOSE AND SCOPE

### 1-1. PURPOSE

The purpose of this manual is to provide pertinent data in a convenient format for officers and noncommissioned officers at the *platoon level*.

### 1-2. SCOPE

*a. Contents.* Data has been condensed on a wide variety of subjects. These subjects apply especially to the duties of engineer unit personnel, particularly officers and noncommissioned officers in *combat Engineer units where mobility is important and the constantly changing missions prevent the use of other references.*

*b. Comments.* The proponent agency of this publication is the United States Army Engineer School. Users of this manual are encouraged to submit comments or recommendations for changes to improve this manual. Comments should be keyed to the specific page, paragraph, and line of text in which the change is recommended. Reasons will be provided for each comment to insure understanding and proper evaluation.

Comments should be prepared using DA Form 2028 (Recommended Changes to Publications) and forwarded directly to the Commandant, U.S. Army Engineer School, Fort Belvoir, Virginia 22060.

## Section II. REFERENCES

### 1-3. MANUALS

Pertinent manuals and other military publications are listed in the appendix.

### 1-4. STANDARD AGREEMENTS

Information in this manual reflects the application of Standard NATO Agreements (STANAG). Applicable STANAG's can be found in the appendix.

### 1-5. SYSTEM OF MEASUREMENT AND ABBREVIATIONS

In accordance with AR 310-3, linear distances used in tactical situations are expressed in the metric system throughout the text. Dimensions of a technical nature are expressed in the English system of measurements. Webster's standard abbreviations, such as "km" (kilometers), "m" (meters), "ft" (feet), and "mi" (miles) are used to clearly identify measurement units. A pace or step in marching (referred to as pace in STANAG 2036) is defined as three-quarters (0.75) of a meter (30 inches). Additional conversion factors are included in tables 16-18 and 16-19.

# EXPLOSIVES AND DEMOLITIONS

## Section I. INTRODUCTION

### 2-1. CHARACTERISTICS OF EXPLOSIVES

- a. Demolitions are primarily used for the rapid creation of obstacles, the reduction of enemy obstacles, and construction blasting. The primary advantages are the limited logistical support requirements and the short time and small crews needed for emplacement and detonation.
- b. See table 2-1 for primary uses of U.S. Military Explosives, and relative effectiveness (RE) factors.

### 2-2. PROBLEM-SOLVING FORMAT

- a. Evaluate the mission and determine the results desired.
- b. Determine the types and quantity of explosives available.
- c. Identify and measure critical dimensions.
- d. Determine the size of the charge(s). The formulas used in this chapter give the weight of explosive (P) required for a demolition task in pounds of TNT. Where any explosive other than TNT is used, the required pounds of explosive are obtained by dividing P by the relative effectiveness factor (RE) for the explosive used (see table 2-1).

If results require a fraction of a package, round up.

*Example:*

$P(\text{TNT}) = 20 \text{ lbs}$  (taken from table or chart)

$$P(\text{C-4}) = \frac{20 \text{ lbs}}{1.34} = 14.91 \text{ lbs of C-4}$$

Using M-112 blocks (1¼ lbs each)

$$\frac{14.91}{1.25} = 11.9 \text{ blocks, use 12 blocks}$$

- e. Determine the total number charges needed.
- f. Determine total amount of explosive required. (Size of charge) x (no. of charges needed) + (explosives required for priming) = total explosives required. (Must be computed for each size charge if more than one size charge is used.)
- g. Calculate safe distance. See paragraph 2-3 and table 2-2.

Table 2-1. Characteristics of U.S. Military Explosives

Explosive	Usage	Det. Vel. (ft/s)	RE Factor	Size, Wgts, & Packaging
TNT	Breaching	23,000	1.00	1 lb: 48-56/Box; ½ lb: 96-106/Box
Tetrytol	Breaching	23,000	1.20	8-2½ lb/Sack, 2 Sacks/Box
C-4 M5A1 & M112	Cut & Breach	26,000	1.34	M5A1: 24-2½ lb Bliks/Box M112: 30-1½ lb Bliks/Box
Sheet Exp M118 M186	Cutting	24,000	1.14	4-½ lb Sheets/Pack W/20 Packs per Box (1 Sheet = 3" x ½" x 12") 3-25 lb Rolls/Box (50' long)
Dynamite M1	Qry/Stump/ Ditch	20,000	0.92	100-½ lb Sticks/Box
Det Cord	Priming	20,000- 24,000		3-1000' Rolls or 8-500' Rolls/Box
Crater Charge	Craters	8,900	0.42	1-40 lb Canister/Box
Bangalore M1A2	Wire & Breaching	25,600	1.17	10-5' Sections/Box (176 lb)
Shaped Charges M2A4 M3A1	Cutting Holes	25,600 25,600	1.17 1.17	3-15 lb Shape Charges/Box 1-40 lb Shape Charge/Box

NOTES:

- Dynamite which is to be submerged under water for a period exceeding 24 hours must be waterproofed by sealing in plastic or dipping in pitch.
- C-4 which is to be used under water must be kept in packages to prevent erosion.

Table 2--2. Minimum Safe Distance for Personnel in the Open

POUNDS OF EXPLOSIVE	SAFE DISTANCE (METERS)	SAFE DISTANCE (FEET)	POUNDS OF EXPLOSIVE	SAFE DISTANCE (METERS)	SAFE DISTANCE (FEET)
1 to 27	300	985	150	532	1745
30	311	1020	175	560	1831
35	327	1072	200	585	1919
40	342	1121	225	609	1997
45	356	1168	250	630	2066
50	369	1210	275	651	2135
60	392	1285	300	670	2198
70	413	1352	325	688	2257
80	431	1413	350	705	2312
90	449	1470	375	722	2365
100	465	1525	400	737	2420
125	500	1640	425	750	2460

Note. All safe distances are determined through use of the following formula and are based on normal expected missile hazard rather than blast effect. Metal fragments can exceed the above distances and require maximum cover.

$$\text{Safe Distance (meters)} = 100 \sqrt[3]{\text{Pounds of Explosive}}$$

Safe distance using missile-proof shelter = 100 meters



## 2-3. SAFETY

- a. Refer to AR 385-63 for necessary safety precautions pertaining to the use of explosives.
- b. Refer to FM 5-25, Explosives and Demolitions, for use of explosives by US Army personnel.
- c. Report receipt of damaged or otherwise unsatisfactory explosive material on DD Form 6 in accordance with AR 700-58.
- d. Report malfunctions in accordance with AR 75-1.
- e. Detonation or burning of ANY explosive releases toxic gases which should not be inhaled. Burning of explosives as a source of heat or for cooking is strictly prohibited since serious illness, injury, or death can be expected.
- f. Specific safe practices for handling, transporting, and firing explosives are prescribed in TM 9-1300-206, TM 9-1375-213-12, and FM 5-25.
- g. *Misfires.*
  - (1) Only ONE person should approach a misfired charge, and then only after an appropriate "cook-off" time has lapsed (minimum of 30 minutes for all nonelectrically primed charges and buried charges).
  - (2) Misfired charges *above ground* should be blown in place with 1 lb of explosive.
  - (3) Misfired charges which are *buried* should be carefully excavated to no closer than 1 foot from the charge and then blown in place with at least 2 lbs of explosive.
  - (4) Never abandon misfired explosives.
  - (5) Never attempt to move or disarm misfires.

h. **HANDLE EXPLOSIVES CAREFULLY! DO NOT TAKE CHANCES!**

## 2-4. METHODS OF PRIMING

- a. *Detonating cord priming* is the use of detonating cord to initiate an explosive charge. When used as a primer, it is not considered as part of the charge it initiates. Detonating cord is initiated as part of either an electric or nonelectric firing system. *It is the most simple, safe, and versatile method of*

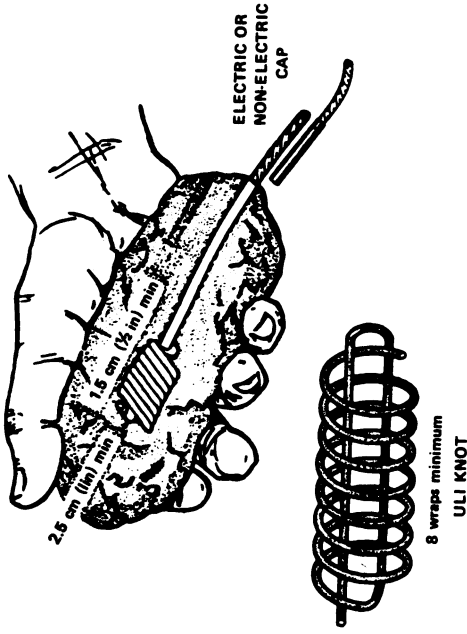


Figure 2-1. Detonating cord priming using plastic explosives.

- b. *Electric priming* is the use of an electric cap to initiate an explosive charge. It has the advantage of command detonation but requires additional equipment.
- c. *Nonelectric priming* is the use of a nonelectric cap to initiate an explosive charge. It cannot be command detonated but requires less equipment than electric priming.
- d. All explosive charges should be dual primed to insure detonation. See paragraph 2-5.

## 2-5. FIRING SYSTEMS

A firing system is a complete means of detonating a charge and includes a primer. A dual-firing system is two completely separate firing systems, each of which can detonate the charges. Possible dual systems are:

- a. *Dual Electric.*
- b. *Dual Nonelectric.*
- c. *Combination Dual System (1 Electric, 1 Nonelectric) (fig. 2-2).*

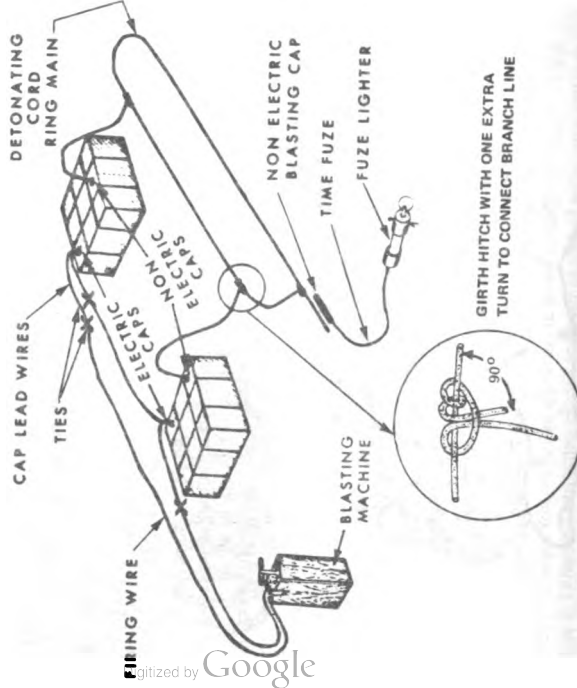


Figure 2-2. Combination dual-firing system.

## **2-6. OBSTACLE PLANNING CONSIDERATIONS**

- a. The combat mission of the unit being supported.
- b. Any limitations or instructions issued by higher authority.
- c. The current tactical and strategic situation.
  - (1) The length of time the enemy must be delayed.
  - (2) The time available to prepare the obstacle.
  - (3) Direct and indirect supporting fires available.
- d. Tie in with other natural or man-made obstacles and plans for effective covering fire.
- e. Requirements for lanes and gaps and concealment of mines.
- f. The manpower needed to guard and maintain the demolitions while awaiting authority to fire.
- g. The materials and equipment available.
- h. The possibility that friendly forces will soon reoccupy the area and require the obstacle to be neutralized.
- i. The immediate and long term effect on the local population.

## **2-7. BRIDGE DEMOLITION**

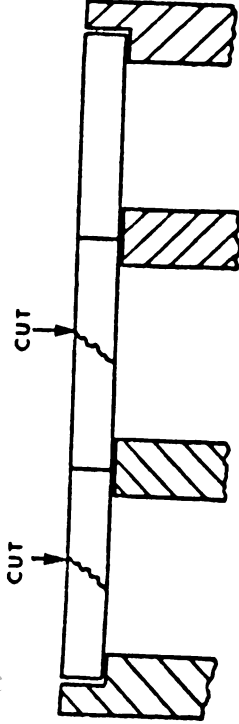
Generally, bridges are demolished to create obstacles which delay the enemy; however, bridges seldom require complete destruction. The method used for demolition should normally permit the economical reconstruction of the bridge by friendly troops in future operations. Normally, the needed delay can be obtained by blasting a gap that exceeds the capability of the prefabricated high-speed bridging available to the enemy where the construction of an intermediate support will be difficult or impossible. All bridges, because of differences in size, design, and construction materials present individual peculiarities and problems which must be considered, such as

- a. How are the spans of the bridge supported and what will be the results of cutting each at various points?
- b. Which parts will be easiest to cut with demolitions, what is the extent of desired destruction, and what will be the difficulty of repair?

- c. What are the desired points of cut (figs. 2-3 through 2-20)? (Consider the special means of cutting each type of span.)
- d. Has each member in the plane of cut been identified and spaned?
- e. Is the problem-solving format being followed? See paragraph 2-2.
- f. Who has authority to detonate or disarm?
- g. Destroyed span should be hardest for enemy to replace.
- h. Single abutment destruction should be the friendly side.
- i. Piers should be breached at an angle.
- j. On very large bridges, consider creating a gap in the approaches instead of the bridge.

## 2-8. BRIDGE SPAN TYPES

- a. *Multiple Simple Span (fig. 2-3).* Mid-span is most critical point and span ends are normally unsecured. If the gap is shallow, multiple cuts are needed to insure dropping the span completely. If necessary, two or more spans and piers can be cut to obtain the needed gap.



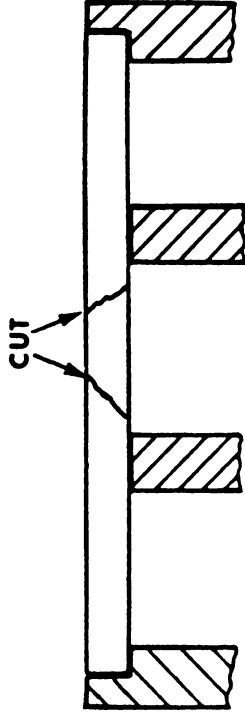


Figure 2-4. Continuous span.

- c. Cantilever With Suspended Span (fig. 2-5). Suspended span may be pin connected.

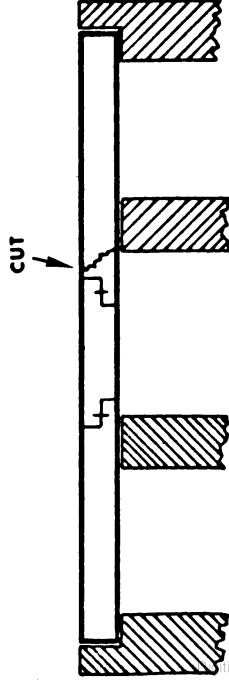


Figure 2-5. Cantilever with suspended span.

## 2-9. SPAN ANALYSIS

- Timber Spans. Cut stringers using timber cutting calculations.
- Steel Stringer Span (fig. 2-6). Cut stringers at different lengths near the plane of cut.

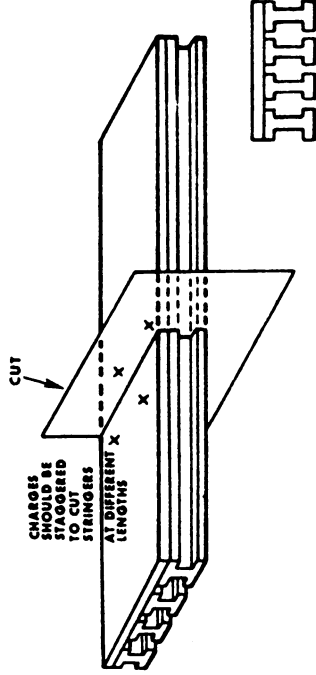


Figure 2-6. Steel stringer span.

c. *Through Truss (fig. 2-7).*

(1) Method 1 — cut all members where intersected by the plane. Cut in three places if the gap is shallow.

(2) Method 2 — if clearance below the bridge is more than the maximum diagonal truss height (D), four charges, placed on the upstream side at the points marked with an "x," will rotate and totally destroy the span.

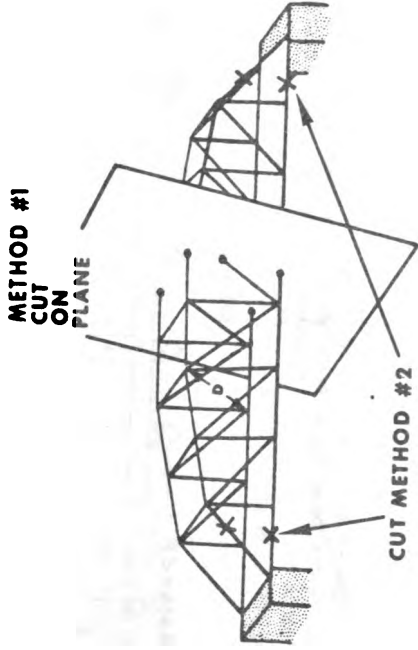


Figure 2-7. Through truss.

d. Deck Truss (fig. 2-8). Cut the same as the through truss.

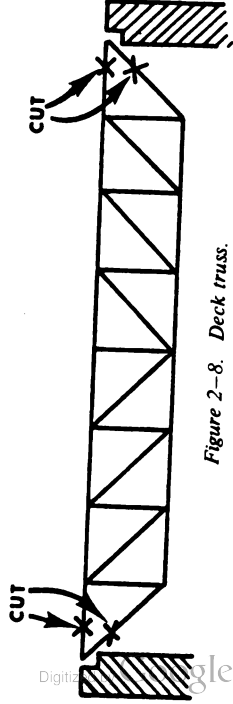


Figure 2-8. Deck truss.



e. *Plate Girder (fig. 2-9).*

- (1) Method 1 — totally cut one girder at A and one at B for total destruction.
- (2) Method 2 — cut both girders at either A or B for deep gaps.

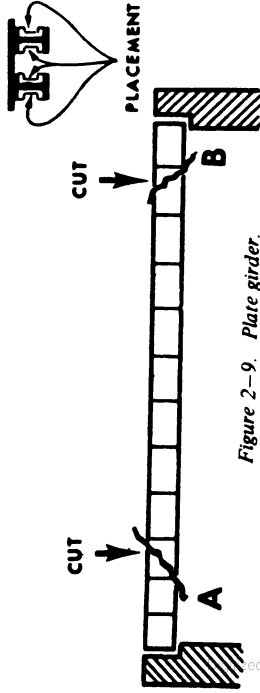
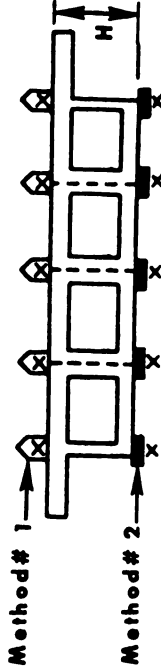


Figure 2-9. Plate girder.

*Concrete Box Beams (Long Spans) (fig. 2-10).* Long prestressed box beams require special charges as the location of the internal openings cannot always be determined prior to demolition. In cases of very massive beams of this type, it may be more efficient to attack the substructure.

### END VIEW



use shaped charges to cut all webs (fig. 2-10).

(2) Method 2 — external breaching charges can be placed at the joints between the box beams or next to the webs (fig. 2-10).

g. *Filled Arch Bridge.*

(1) Method 1 — cut at point A with charges placed on the arch ring, i.e., dig down to the arch ring or place beneath (fig. 2-11).

(2) Method 2 — place charges on the arch ring at points B.

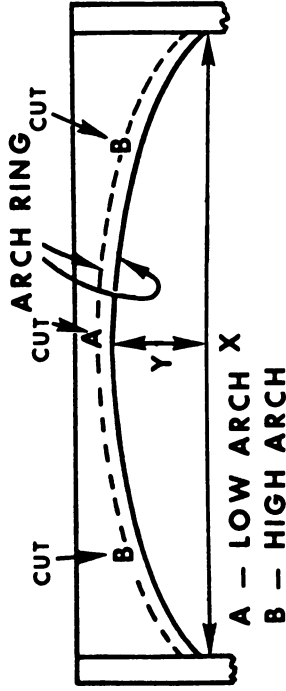


Figure 2-11. Filled arch bridge.

h. *Open Spandrel Arch (fig. 2-12). Cut at points A, B, and C.*

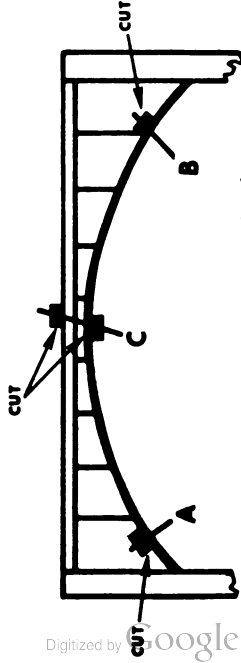


Figure 2-12. Open spandrel arch.

- i. *Concrete T Beam (fig. 2-13). Breach the top, bottom, or side beams with 40 pound shaped charge.*

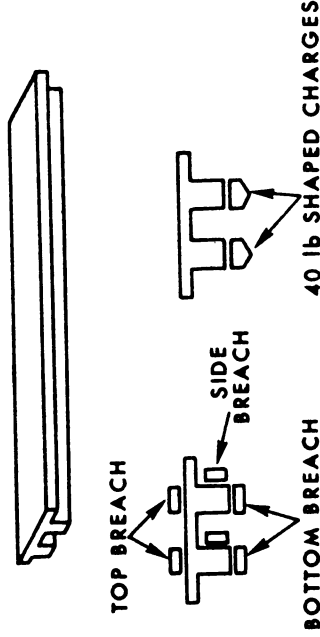


Figure 2-13. Concrete T beam.

- j. *Concrete Slab (Short Spans) (fig. 2-14). Top breach, bottom breach, or breach as a big box beam.*

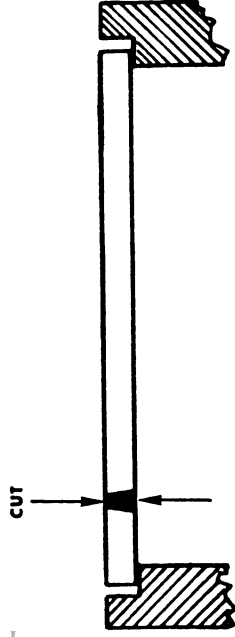
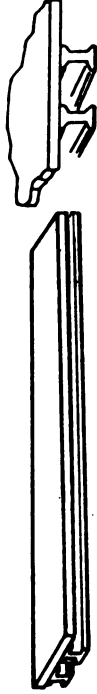


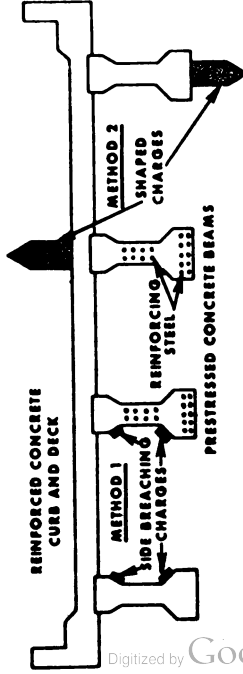
Figure 2-14. Concrete slab (short spans).

k. *Concrete I Beams (fig. 2-15).* As a result of the thin webs and high strengths, a special means is needed to destroy these prestressed beams.



*Figure 2-15. Concrete I beams (prestressed).*

- (1) Method 1 — For beams with a height of 1 meter or less, place charges as shown in figure 2-16 (side breaching charges) with 3 lbs on the bottom flange and 2 lbs on the top flange. Detonate simultaneously. Charges should be placed at mid-span to take maximum advantage of bridge weight.
- (2) Method 2 — Totally destroy the web with a shaped charge placed at either the top or the bottom.



*Figure 2-16. Concrete I beams.*

## 2-10. ABUTMENT AND PIER DEMOLITION

- a. Over 5 feet in thickness and over 20 feet in height (see fig. 2-17).

T = more than 5 ft.

Breaching formula  $P = R^3 KC$  (para 2-12)

Compute the charges for the river face and for behind the abutment separately.

$$\text{Number of charges (N)} = \frac{W}{2R}$$

W = Abutment width

R = Breaching radius

Place on both sides of abutment, as shown in figure 2-17, and fire simultaneously.

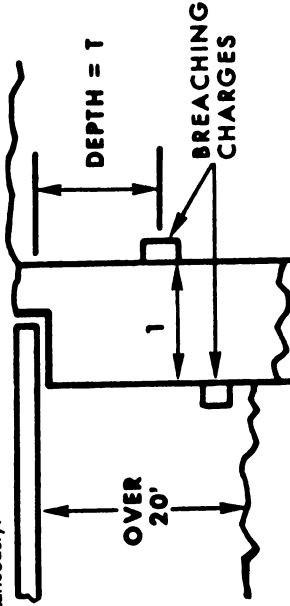


Figure 2-17. Abutment demolition ( $T > 5'$ ).

- b. Over 5 feet in thickness but 20 feet or less in height. Use the solution in 2-10a but delete the charges on the river face.

- c. 5 feet or less in thickness and over 20 feet in height (see fig. 2-18).

T = 5 ft. or less

Space 40 lb charges, 5 ft. back from the river face, 5 ft. deep, and 5 ft. apart.

Breaching charges  $P = R^3 KC$  (river face)

$$N = \frac{W}{2R}$$

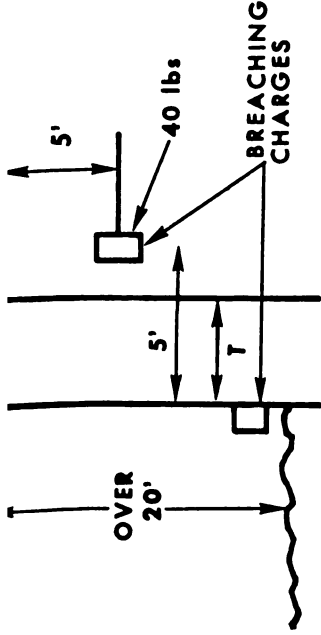


Figure 2-18. Abutment demolition ( $T \leq 5'$ ).

- d. Five feet or less in thickness and 20 feet or less in height. Use solution in 2-10c but delete the charges on the river face.
- e. *Pier Demolition.* Piers must be breached on an angle and as low as possible to maximize engineer repair effort (fig. 2-19).

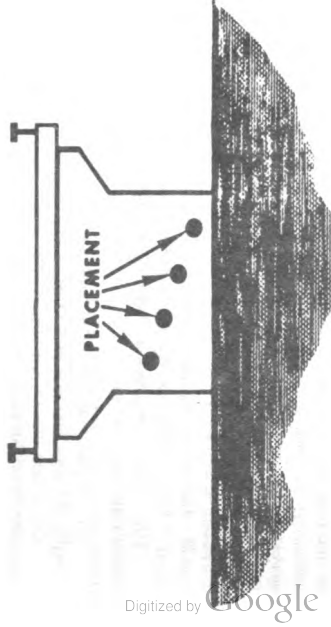


Figure 2-19. Pier demolition.

f. *Counterforce Charge* (fig. 2-20). The counterforce charge is a pair of opposing charges used to fracture small concrete or masonry cubes and cylindrical columns with thicknesses of 4 feet or less. It is not effective against reinforced concrete piers or long obstacles such as walls.  $P = 1\frac{1}{2} \times T$  (thickness in feet)

*Example:*

Column 3 ft. by 3 ft.

$P = 1\frac{1}{2} \times 3$

$P = 4.5$  lbs total C-4 or sheet explosive

(1) Round fractional measurements to the next higher foot prior to multiplying.

(2) Divide the calculated amount of explosive into two identical charges and place opposite each other.

(3) Place cap or Uli knot in the exact rear centers of charges and detonate simultaneously.

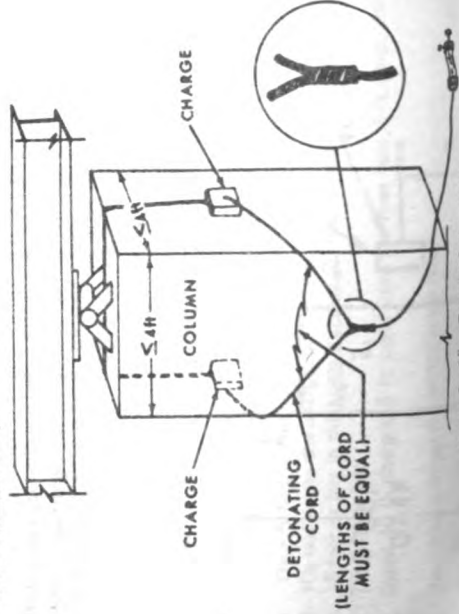


Figure 2-20. Counterforce charge.

g. *Breaching Hard-Surfaced Pavements.*

- (1) Use 1 pound of explosives for each 2 inches of pavement. Tamp with material twice as thick as the pavement.
- (2) Use a shaped charge. See paragraph 2-19 for sizes.

### Section III. CHARGE CALCULATIONS

#### 2-11. STEEL CUTTING CHARGES

Optimum target to explosive contact and dimensions are the most critical factors in steel cutting. The following methods, based on explosive availability, are recommended for demolition steel cutting missions.

- a. *Ribbon Charge.* Used on flat, structural steel (I-beams, wide flange beams, plates, etc.) up to 3 inches in thickness with the following parameters:

Charge Thickness ( $T_c$ ) = one-half the thickness of steel member ( $T_s$ )

$$T_c = \frac{1}{2}T_s$$

Charge Width ( $W_c$ ) = three times charge thickness ( $T_c$ )

$$W_c = 3T_c$$

Charge Length ( $L_c$ ) = length of desired cut ( $L_s$ )

$$L_c = L_s$$

- (1) Charge thickness must be a minimum of  $\frac{1}{8}$  inch regardless of steel thickness. Plastic explosive (C-4) *must be cut* rather than molded to preserve explosive density.
- (2) Ribbon charges may be constructed using entire sheets of M118 sheet explosive or blocks of M112 C-4 explosive as long as the minimum charge dimensions are equal to or larger than those specified above in paragraph 2-11a.
- (3) Correct placement of the ribbon charge requires close target-to-explosive contact over the entire length of steel to be cut (fig. 2-21).



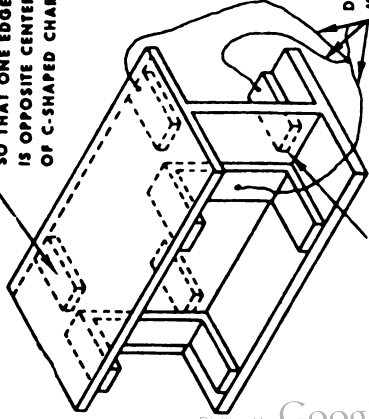
**BEAMS LESS THAN 2 INCHES THICK:**

OFFSET FLANGE CHARGE

SO THAT ONE EDGE

IS OPPOSITE CENTER

OF C-SHAPED CHARGE



**PRIMING:**

DETONATING CORD PRIMERS

MUST BE OF EQUAL LENGTH

**BEAMS 2 INCHES THICK OR MORE:**

OFFSET FLANGE CHARGE

SO THAT ONE EDGE

IS OPPOSITE AN EDGE

OF THE C-SHAPED CHARGE

*Figure 2-21. Ribbon charge.*

*b. Saddle Charge. Used on solid cylindrical structural steel bars up to 6 inches in diameter. It is triangular in shape and 1 inch thick with the long axis equal to the bar circumference and the short axis equal to one-half the bar circumference. It may also be used on solid rectangular or square bars (up to 8 inches square) but with slightly greater charge placement flexibility.*

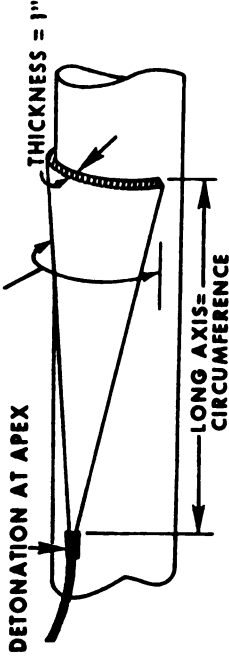


Figure 2-22. Saddle charge.

c. *Diamond Charge.* Used on solid cylindrical steel bars up to 6 inches in diameter. It is diamond shaped, 1 inch thick, with the long axis equal to the circumference of the bar and the short axis equal to one-half the bar circumference. It may be used on rectangular or square bars, but placement around corners is extremely difficult. It is primed at the apex of both ends of the short axis with exactly equal lengths of detonating cord in conjunction with either nonelectric caps or Uli knots. The detonating cord is then joined together at the ring main. The explosive should be cut rather than molded (fig. 2-23).

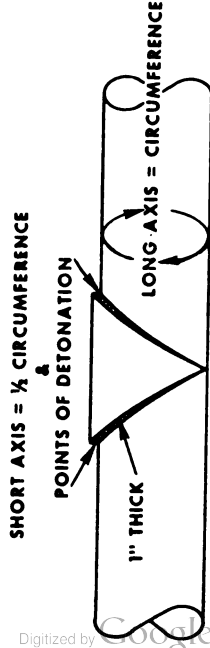


Figure 2-23. Diamond charge.

d. The steel cutting formula is still acceptable when only hard block explosives are available.

*Steel cutting formula*  $P = (\frac{3}{8})A$

P = pounds of TNT required

$\frac{3}{8}$  = constant

A = cross-sectional area of member in square inches.

See problem--solving format, paragraph 2-2.

e. *Rules of Thumb (Steel Cutting).* Rules of thumb for steel cutting give the required explosive quantities in pounds of TNT and *do not* require dividing by an RE factor.

(1) *Rails (cut preferably at crossings, switches, frogs, or curves).* Cut at alternate rail splices for a distance of 500 feet.

(a) Less than 5 inches high — use  $\frac{1}{2}$  pound.

(b) Five inches or higher — use 1 pound.

(c) Crossings and switches — use 1 pound.

(d) Frogs — use 2 pounds.

(2) *Cables, chains, rods, and bars.*

(a) Up to 1-inch diameter — use 1 pound.

(b) Over 1 inch to 2 inches — use 2 pounds.

(c) Over 2 inches — use  $P = (\frac{3}{8})A$  or suitable dimensional—type charge.

(3) *Note.* Chain and cable rules are for those under tension; both sides of chain link must be cut.

## 2-12. BREACHING CHARGE COMPUTATIONS

a. *Breaching Formula.*

$P = R^3 KC$  where

P = pounds of TNT required

R = breaching radius in feet

K = material factor (strength); table 2-3



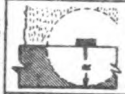

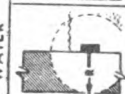
C = tamping factor; table 2-4

- (1) For external charges based on  $P = R^3 KC$ , use a minimum of 5 pounds for reinforced concrete and 3 pounds for dense concrete.
- (2) Round up "R" to nearest ½ foot.
- (3) When type of concrete is unknown, always assume it to be reinforced.

Table 2-3. Values of K (Material Factor) For Breaching Charges

Material	Breaching radius	K
Ordinary earth	All values	0.07
Poor masonry, shale, hardpan: Good timber and earth construction	Less than 5 ft 5 ft or more	0.32 0.29
Good masonry ordinary concrete rock	1 ft or less 1.5-2.5 ft 3.0-4.5 ft 5.0-6.5 ft 7 ft or more	0.88 0.48 0.40 0.32 0.27
Dense concrete first-class masonry	1 ft or less 1.5-2.5 ft 3.0-4.5 ft 5.0-6.5 ft 7 ft or more	1.14 0.62 0.52 0.41 0.35
Reinforced concrete (concrete only: Will not cut reinforcing steel)	1 ft or less 1.5-2.5 ft 3.0-4.5 ft 5.0-6.5 ft 7 ft or more	1.76 0.96 0.80 0.63 0.54

Table 2-4. Values of Tamping Factor "C"






INTERNAL STEMMED	DEEP WATER	ELEVATED SHALLOW WATER	GROUND PLACED	GROUND UNTAMPED
				
C=1.0	C=1.0	C=1.8	C=2.0	C=3.6

IF THE BREACHING RADIUS IS GREATER THAN THE DEPTH OF WATER, USE 2.0.  
IF EQUAL TO OR LESS THAN THE DEPTH OF WATER, USE 1.0.

b. *Breaching Table.* Table 2-5 gives the pounds of TNT required to breach reinforced concrete targets, calculated from the formula  $P = R^3 KC$ . For material other than reinforced concrete, multiply by the conversion factor in table 2-6.

## 2-13. TIMBER CUTTING CHARGES

- Test shots are made to determine the required amount of explosives to cut specific types of timber. This section provides charge calculations for initial test shots only.
- External Placement.*  $P \text{ (TNT)} = \frac{D^2}{40}$ . Use to cut trees, poles, piles, posts, beams, and other timber with external untamped charges. Use graph (fig. 2-24) to calculate amount required, and place as shown in figure 2-25 (D = diameter in inches).

THICKNESS OF CONCRETE	METHODS OF PLACEMENT				
					
	C=1.0	C=1.8	C=2.0	C=3.6	
FEET	POUNDS OF TNT				
2	2	8	14	16	28
2½	2	15	27	30	54
3	4	22	39	44	78
3½	6	35	62	69	124
4	8	52	93	103	185
4½	11	73	132	146	263
5	15	79	142	158	284
5½	20	105	189	210	378
6	22	136	245	273	490
6½	28	173	312	346	623
7	35	186	334	371	667
7½	43	228	410	456	821
8	52	277	498	553	996

TO USE TABLE:

1. MEASURE THICKNESS OF CONCRETE
2. DETERMINE METHOD OF PLACEMENT
3. NOTE TNT REQUIRED ACCORDING TO METHOD OF PAYMENT
4. IF USING EXPLOSIVE OTHER THAN TNT DIVIDE BY RE FACTOR FOR ALL METHODS OF EMPACEMENT EXCEPT INTERNAL.
5. TO DETERMINE REQUIRED NUMBER OF CHARGE:

$$N = \frac{W}{2R} \quad \text{WHERE: } W = \text{WIDTH OF TARGET}$$

$$R = \text{BREACHING RADIUS (ft)}$$

NOTES:

- (1) PLACE FIRST CHARGE "8" DISTANCE FROM END OF TARGET AND ALL OTHER CHARGES "2R" DISTANCE APART.
- (2) FOR BEST RESULTS PLACE CHARGE IN SHAPE OF A FLAT SQUARE
- (3) FOR CHARGES LESS THAN 40 LBS USE CHARGE THICKNESS OF 2 INCHES
- (4) FOR CHARGES 40-300 LBS USE CHARGE THICKNESS OF 4 INCHES

Table 2-6. Conversion Factors For Material Other Than Reinforced Concrete

Earth	Ordinary masonry, hardpan, shale, ordinary concrete, rock, good timber and earth construction	Dense concrete, first-class masonry
0.1	0.5	0.7

c. *Internal Placement.*  $P \text{ (ANY)} = \frac{D^2}{250}$ . Use graph (fig. 2-24) for proper calculation of explosive required. (D = diameter in inches).

d. *Abatis.*  $P \text{ (TNT)} = \frac{D^2}{50}$ . To create an abatis, use graph for initial calculation and place as an external charge. Results should leave tree attached to stump at a height of 3-5 feet. Minimum tree diameter for an effective abatis is 18 in. for wheeled vehicles and 24 in. for tracked vehicles (D = diameter in inches).

e. *Ring Charges.* (For diameters 30 in. or less)

(1) *Calculations.*

(a) M118 or M186 sheet explosive;  $\frac{1}{2} \times \text{circumference (ft)} \times \text{No. wraps} = \text{lbs.}$

(b) C-4;  $1.36 \times \text{circumference (ft)} \times \text{No. wraps} = \text{lbs.}$

(c) As an alternate method, use  $P = \frac{D^2}{40}$  (D = diameter in inches)

(2) *Placement (fig. 2-25).*

(a) Explosive must be wrapped completely around timber in order to be effective, tamp if possible.

(b) Direction of fall can be controlled only with ropes and cables.

## 2-14. CRATERING CHARGES

a. *Requirements.* Road craters, in order to be effective obstacles, must

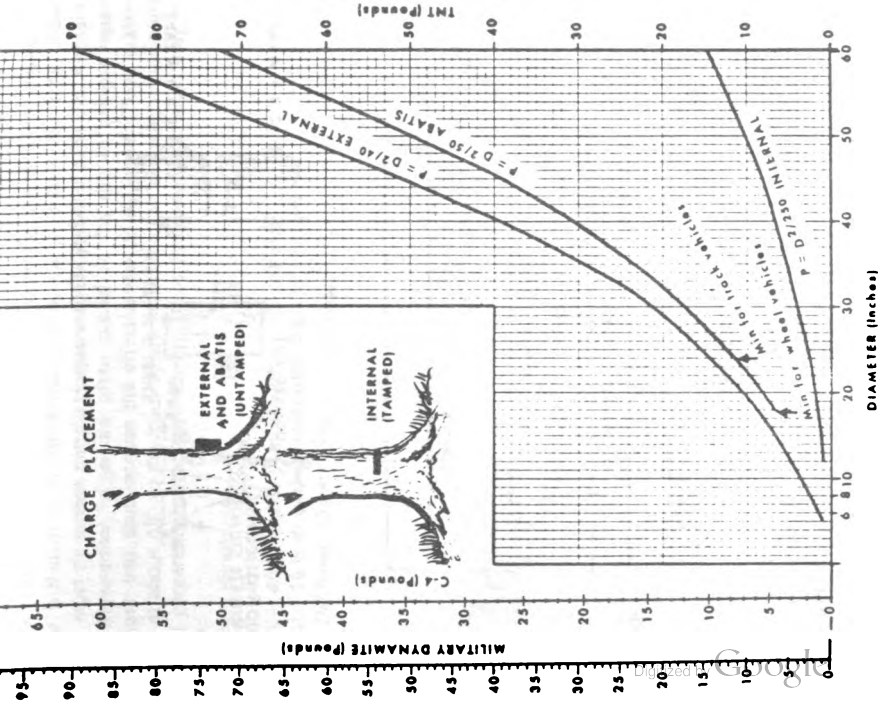


Figure 2-24. Timber cutting calculations.

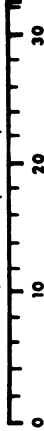


## a. QUANTITY

NUMBER OF WRAPS OF SHEET EXPLOSIVE

1	2	3	4	5
---	---	---	---	---

DIAMETER (INCHES)



CIRCUMFERENCE (FEET)



NUMBER OF WRAPS OF C-4

1	2
---	---

## b. PLACEMENT

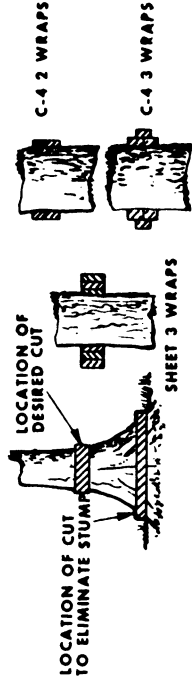


Figure 2-25. Timber cutting charges.

the tank requires three or more passes to cross the crater. Three passes will provide sufficient time for antitank weapons to disable the tank. Road craters must tie in with natural or man-made obstacles at each end. Antitank and antipersonnel mines are often placed at the site to hamper repair operations and thus increase the effectiveness of the crater. Road craters angled at about 45° to the roadway are more effective obstacles than craters blasted perpendicular to the roadway. Holes for cratering charges may be dug by:

- (1) Handtools
- (2) Earth auger
- (3) 40 lb shaped charges with a 5-ft. standoff
- (4) 15 lb shaped charges with a 3.5-ft. standoff

b. *Deliberate Crater.* See figure 2-26.

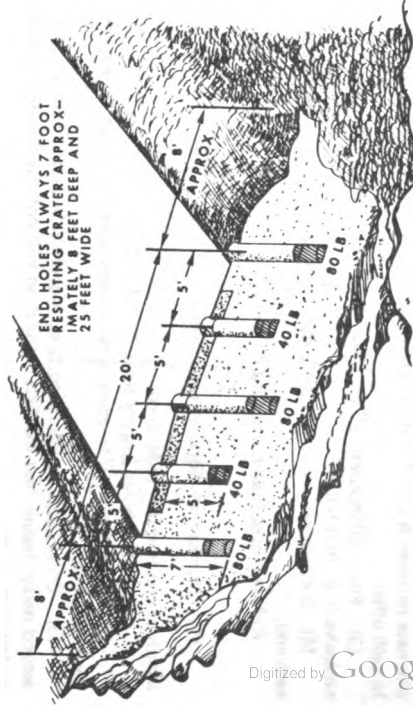


Figure 2-26. Charge placement for deliberate road crater.

- (1) Number of holes ( $N$ ) =  $\frac{L-16}{5} + 1$ , where  $L$  = total length of the crater in feet.
  - (2) Holes are 5 feet apart with both end holes 7 feet deep; holes alternate between 5 and 7 feet in depth, but no two 5 ft. holes may be next to each other.
  - (3) Place 80 pounds of explosive in 7-foot holes; 40 pounds of explosive in 5-foot holes.
  - (4) Excavation will result with approximately 8 feet of overblast on each end.
- c. *Relieved Face Crater.* See figure 2-27.

- (1) Number of holes (friendly side):  $N = \frac{(L-10)}{7} + 1$ , where  $L$  = length of crater in feet (5 ft. deep).

Number of holes (enemy side):  $N - 1$  (4 ft. deep).

- (2) Place 2 rows 8 ft. apart, spacing boreholes 7 ft. apart in each row. See figure 2-27.
- (3) Enemy side is detonated first, friendly side second with a 1 to 1½ second delay. Insure that the first detonation will not cut the firing system on the second row.

d. *Hasty Crater.* Figure 2-28.

- (1) Holes of equal depth spaced at 5-foot intervals: Place 10 pounds of explosives per foot of depth; resulting crater will be approximately 1½ times the depth of boreholes and 5 times the borehole depth in width (fig. 2-28).
- (2) Boreholes should be a minimum of 5 feet in depth.
- (3) Number of holes =  $N = \frac{L-16}{5} + 1$
- (4) This crater is not as effective as a deliberate or relieved face crater but is excellent when preparing surfaced areas for mining.

## 2-15. DESTRUCTION OF ENEMY OBSTACLES

- a. *Combat Engineer Vehicle (CEV).* The CEV provides engineer

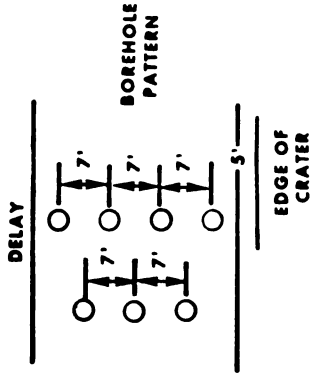
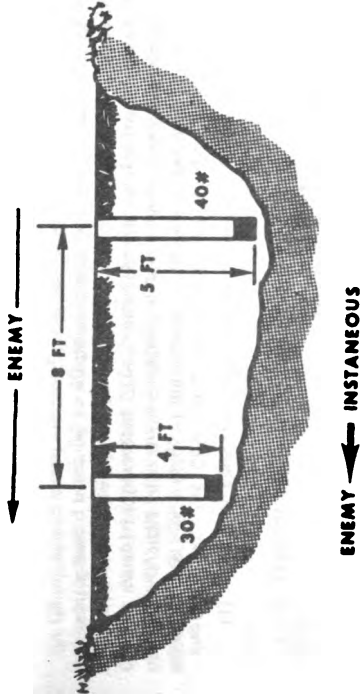


Figure 2-27. Relieved face crater.

HOLES OF EQUAL DEPTH, SPACED AT 5-FOOT INTERVALS. USE 10-POUNDS OF EXPLOSIVES PER FOOT OF DEPTH. RESULTING CRATER DEPTH APPROX.  $1\frac{1}{2}$  TIMES DEPTH OF BOREHOLES. WIDTH APPROX. 5 TIMES DEPTH OF BOREHOLES.

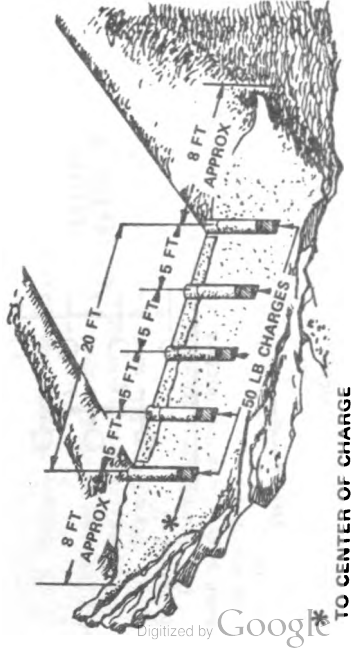


Figure 2-28. Charge placement for hasty road crater.

engineer tasks. The CEV has a 165-mm demolition gun, which has a maximum effective range of 900 meters. It can hit a 6 ft. by 6 ft. target consistently. The minimum safe distance from the impact area for personnel in the open is 1200 meters. The primary use of the gun is to remove obstacles such as roadblocks, log cribs, trees, and to destroy enemy bunkers without exposing personnel to enemy small arms fire. If a dud round occurs, the round remains armed and should be blown in place.

(1) *Concrete block obstacles.* Use 1 pound of explosive per cubic foot of volume up to 100 cubic feet.

(2) *Log obstacles.* Generally the charge should be placed at a joint. Against log cribs, place 30 to 40 pounds of explosives in the center of the earth fill, two-thirds down the depth of the crib, and tamp, if possible. Charges should be placed at 8 foot intervals throughout the length of the obstacle. Charges placed on obstacles driven into the ground should be attached below or as close to the surface of the ground as possible.

### *c. Walls.*

(1) Concrete walls not backfilled: use breaching formula in paragraph 2-12.

(2) Backfilled walls: multiply by 1.2 the charges specified for walls not backfilled.

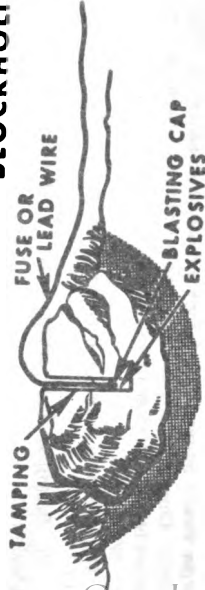
## **Section IV. ROCK BREAKING, DITCHING, AND STUMPING**

### **2-16. BLASTING BOULDERS**

See table 2-7 for charge size for blasting boulders. See figure 2-29 for placement of charges. External breaching charges may be used as an expedient.

*Table 2-7. Charge Size For Blasting Boulders*

Boulder diameter (ft)	Pounds of explosive required		
	Blockholing	Snakesholing	Mudcapping
3	$\frac{1}{4}$	$\frac{1}{4}$	2
4	$\frac{3}{8}$	2	3 $\frac{1}{2}$
5	$\frac{1}{2}$	3	6

**SNAKEHOLING****MUD TAMPING MUDCAPPING****BLOCKHOLING**

*Figure 2-29. Methods of blasting boulders.*

*a. Conditions.* Rough open ditches 1 to 4 m deep and 1 to 20 m wide can be blasted in most types of soil, other than gravel or sand. Trees, stumps, and large boulders are charged separately, but are fired with the ditching charges.

*b. Test Shots.* Before beginning the ditching, test shots are required to determine the proper depth, spacing, and weight of charges needed for the desired results.

*c. Detonation.* Begin with holes 2 feet deep and 18 inches apart for soft ground. The depth of the hole is normally 1 foot above the gradeline of the ditch.

*d.* Use 1 pound of explosive per cubic yard of material to be removed. Test and adjust as needed.

## **2-18. STUMPING**

*a.* Use a ring charge at ground level if speed is important and the roots can remain in place.

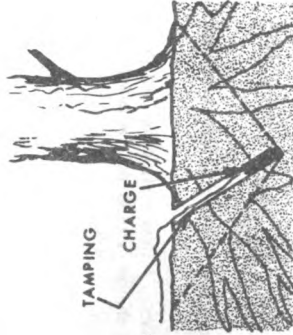
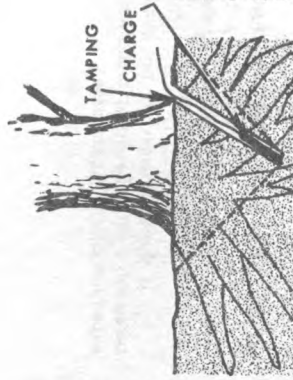
*b.* The size of the charge required varies with the size, variety, and age of the tree or stump and with soil conditions. The rules of thumb (fig. 2-30) must be adjusted based on test results.

## **2-19. BREACHING HARD SURFACE PAVEMENTS**

*a. Shaped Charges.* Table 2-8 shows the size of boreholes obtained by using the standard shaped charges.

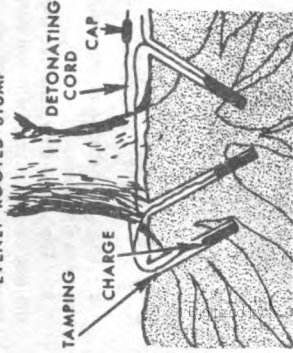
*b.* If shaped charges are not available, follow instruction outlined in paragraph 2-10g. Pavement breaching charges should not be placed at an expansion joint in the concrete.



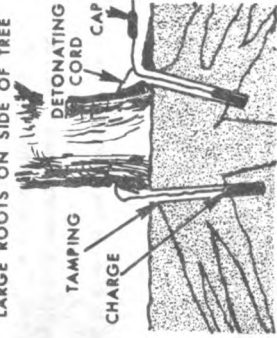


EVENLY ROOTED STUMP

LARGE ROOTS ON SIDE OF TREE



LARGE LATERAL BRACE ROOTS



HEAVY TAP ROOT AND STRONG

BRACE ROOTS

**RULES OF THUMB. USE DYNAMITE AS FOLLOWS:**

- (1) FOR DEAD STUMPS - 1 POUND PER FOOT OF DIAMETER.
- (2) FOR LIVE STUMPS - 2 POUNDS PER FOOT OF DIAMETER.
- (3) FOR STANDING TIMBER - ADD 50 PERCENT FOR STANDING TIMBER.

Material		15 lb. shaped charge (M2A4)	40 lb. shaped charge (M3A1)
Reinforced Concrete	Max. well thickness that can be perforated	36"	60"
	Depth of penetration in thick wells	30"	60"
	Average diameter of hole	2 3/4"	3 3/4"
	Minimum diameter of hole	2"	2"
Armor Plate	Penetration	12"	20" (at least)
	Average diameter of hole	1 1/4"	2 1/2"
3" concrete pavement with 24" rock base course	Optimum standoff	3 3/4"	Equal to or greater than
	Min. depth of penetration	36" - 60"	shown below
	Min. diameter of hole	3 3/4"	for 10" concrete
10" concrete pavement with 21" rock base course	Optimum standoff	3 3/4"	5'
	Depth of penetration	44" - 91"	71" - 109"
	Min. diameter of hole	1 1/4"	6 3/4"
Soil	30" standoff:		
	Diameter of hole	7"	
	Depth of hole	7'	
	48" standoff:		
	Diameter of hole		14 1/2"
	Depth of hole		7'
Permafrost	Diameter of hole w/30" standoff	1 1/2" to 6"	
	Depth of hole w/30" standoff	6'	
	Depth of hole w/42" standoff	5'	
	Diameter w/50" standoff		5" to 8"
	Depth w/50" standoff		6'
Ice	Diameter w/42" standoff	3 3/4"	6"
	Depth w/42" standoff	7'	12'

## CHAPTER 3

## LANDMINE WARFARE

## Section I. INTRODUCTION

## 3-1. TYPES OF MINES

See table 3-1 for standard U.S. mines and firing devices.

## 3-2. TYPES OF MINEFIELDS AND EMPLOYMENT

Minefields are classified into five types according to their function and method of employment.

a. *Types.*

(1) *Protective minefield (hasty or deliberate).* No set pattern. Antihandling devices and nonmetallic mines should not be used. Protective minefields are particularly suitable for directional mines.

(a) *Hasty.* Used to provide local close-in protection. Mines should be readily detectable and facilitate rapid removal by the laying unit. Boobytraps and antisturbance and antihandling devices *will not* be used. Authority to lay is battalion — can be delegated to company or platoon for a specific operational mission.

(b) *Deliberate.* Used to provide local protection for semifixed installations. Normally, mines are buried and the minefield is semipermanent in nature. Authority to lay is the installation commander.

(2) *Tactical minefield.* Used to stop, delay, or disrupt an enemy attack, to reduce enemy mobility, to block penetrations, and to strengthen manned positions. May be used behind enemy forces in order to deny withdrawal, prevent reinforcement, or protect friendly flanks. Conventional mines will be laid in a standard minefield pattern, but scatterable mines may also be integrated into the minefield. Authority to lay is division — can be

# M14 BLAST ANTIPERSONNEL MINE




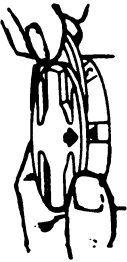


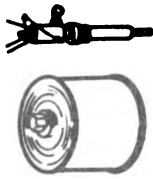
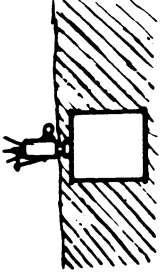
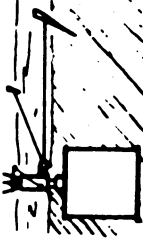


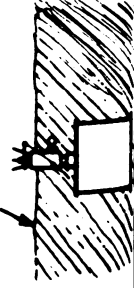
<p>1</p> 	<p>2 Wt ..... 3 1/3 oz. Explosive ..1 oz. TETRYL Fuze ..... integral (with Belleville Spring) Functioning 20 to 35 lb. Penetrate Boot &amp; Foot</p>	<p>3</p>  <p>Unscrew shipping plug from bottom of mine. Turn pressure plate to ARMED position with arming tool.</p>	<p>5</p>  <p>Replace safety clip.</p>
		<p>7</p>  <p>Bury mine and remove safety clip.</p>	<p>6</p>  <p>Screw detonator into detonator well.</p> <p>8 TO BURY: Pressure plate should be slightly above ground level. TO DISARM: Insert safety clip and remove detonator. CAUTION: Repeated turning of arming dial may cause excessive wear.</p>
			<p>4</p>  <p>Remove safety clip and check for malfunctioning.</p>

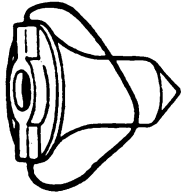
Table 3-1. Mine Data (Con't)

**M16A1 BOUNDING ANTIPERSONNEL MINES**

<p><b>1</b></p> 	<p><b>5</b></p>  <p>Tripwire installation</p>
<p><b>2</b> Wt ..... 8.25 lb.          Projectiles ..... Steel          Fuze ..... M605          (Combination)</p> <p>Functioning:          Pressure ... 8 to 20 lbs          Pull ..... 3 to 10 lbs          Bounding Ht .6-1.2m          Casualty radius..... 30m</p>	<p><b>6</b></p>  <p>Attach tripwires — first to anchor, then to pull ring.</p>
<p><b>3</b></p>  <p>Remove shipping plug and screw in fuze.</p>	<p><b>7</b></p>  <p>Remove locking safety pin first. The interlocking pins should fall free. Then remove positive safety.</p>
<p><b>4</b> GROUND LEVEL</p> 	<p><b>8 TO DISARM: Reverse arming procedure.</b></p>

# M25 BLAST ANTIPERSONNEL MINE (ELSIE)

1



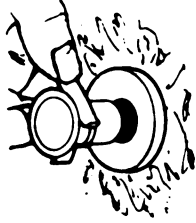
2 Wt ..... 2 3/4 oz.  
Explosive ... 1/3 oz. shape  
charge  
Fuze ..... integral  
(w/ball release)  
Functioning... 14 to 26 lbs  
Penetrate Boot & Foot

3



Push mine into ground.  
Keep dust cap in place. If  
ground is hard, dig hole  
with bayonet.

5



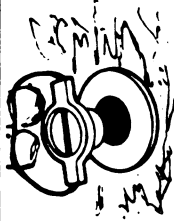
Insert charge.

6



Remove safety clip.

4








Remove dust cap.

7

TO DISARM: Reverse  
arming procedure.

Table 3--1. Mine Data (Con't)

**M26 ANTIPERSONNEL MINE**

<p><b>1</b></p> 	<p><b>2</b></p> <p>Wt ..... 2.2 LBS</p> <p>Projectiles ..... Pellets</p> <p>Fuze ..... integral</p> <p>Functioning:</p> <p>    Pressure ..... 14-28 lbs</p> <p>    Pull ..... 4-8 lbs</p> <p>Bounding Ht ..... 3m</p> <p>Casualty Radius ..... 17m</p>	<p><b>5</b></p>  <p>Attach arming handle to lugs on arming latch, rotate the cover clockwise until it comes to a positive stop (the arrow will point to the red letter "A" armed).</p>	<p><b>6</b></p>  <p>Remove arming latch by pulling straight out with the arming handle.</p>	<p><b>7</b></p> <p>TO DISARM: Reverse arming procedure.</p>
		<p><b>3</b></p>  <p>Remove arming handle. (If tripwire is to be used install trip-lever; attach slack wire to lever; and) place mine in ground flush with top of ground.</p>	<p><b>4</b></p> 	

# M18A1 FRAGMENTATION ANTIPERSONNEL MINE

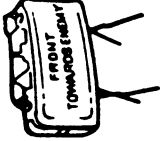



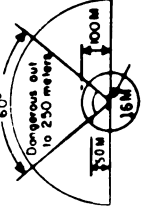
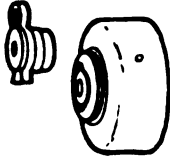
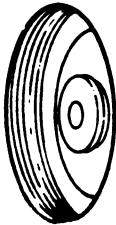
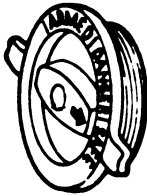

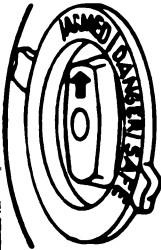
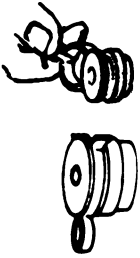
<p><b>1</b></p> 	<p><b>5</b></p>  <p>Remove shipping plug-priming adapter, insert blasting cap and screw into either cap well.</p>
<p><b>2</b></p> <p>Wt ..... 3.5 lbs. Explosive ..... 1.5 lb. C4 Projectiles ..... 700 (steel balls)</p> <p>Equipment: One electric cap 30m firing wire per mine. One electric firing device per mine. One Tester per 6 mines.</p>	<p><b>6</b></p>  <p>Unroll firing wire and connect directly to firing device with safety engaged.</p>
<p><b>3</b></p>  <p><b>TEST CIRCUIT:</b> Mate firing device, circuit tester and blasting cap. Depress handle. Light should show in window. Separate test components.</p>	<p><b>7</b></p>  <p><b>FIRING POSITION:</b> A minimum of 16 meters from rear of mine to fox hole. Friendly troops at side and rear should be under cover at a minimum of 100 meters.</p>
<p><b>4</b></p> <p><b>AIMING:</b> IN AIMING THE M18A1, WHEN USING THE SLIT TYPE PEEP SIGHT, AIM THE MINE AT AN INDIVIDUAL'S HEAD WHEN STANDING 45M FROM THE MINE, WHEN USING THE KNIFE EDGE SIGHT, AIM THE MINE AT AN INDIVIDUAL'S FEET WHEN STANDING 50M FROM THE MINE</p>	<p><b>8 TO FIRE:</b> Disengage safety bail and depress handle.</p> <p><b>9 TO DISARM:</b> Reverse arming procedure.</p>



Table 3-1. Mine Data (Con't)

## M15 HEAVY ANTITANK MINES

<p><b>1</b></p> 	<p><b>5</b></p>  <p>Insert fuze</p>
<p><b>2</b> Wt ..... 30 lbs. Explosive ..... 22 lbs. Fuze ..... M603 Secondary fuze wells ... 2 Functioning: 300 to 400 lbs.</p>	<p><b>6</b></p>  <p>Replace plug with dial in safe position.</p>
<p><b>3</b></p>  <p>Remove plug and inspect fuze well.</p>	<p><b>7</b></p>  <p>Turn dial to ARMED.</p>
<p><b>4</b></p>  <p>Inspect fuze and remove</p>	<p><b>8</b> TO BURY: Put mine in hole with pressure plate at or slightly above ground level.</p> <p><b>9</b> TO DISARM: Reverse</p>

# M15 ANTITANK MINE USED WITH M608 FUZE

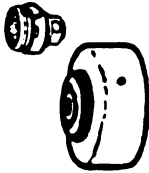
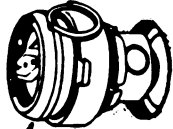
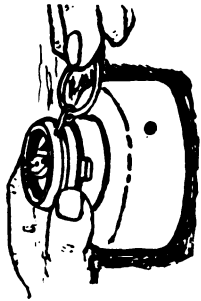

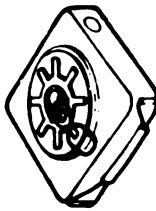
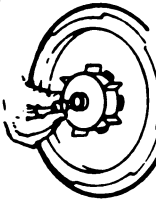


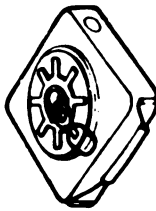


<p><b>1</b></p> 	<p><b>2</b> Functioning . . . 200-350 lbs for 250-450 milliseconds. Resistant to blast type countermeasures.</p>	<p><b>3</b> <b>LOCKING RING</b> <b>FUZE BASE</b></p>  <p>Remove plug and inspect fuze well. Insure fuze is in SAFE position. Thread fuze into mine....<b>HAND TIGHT</b></p>	<p><b>4</b> Hold fuze to prevent rotating, turn locking ring down until it locks against pressure plate.</p>
<p><b>5</b></p> 	<p>Place mine in hole and remove pull pin from fuze.</p>	<p><b>6</b></p>  <p>Turn dial from SAFE to ARMED.</p>	<p><b>7</b> TO DISARM: Reverse procedure except DO NOT replace-pull pin.</p>

Table 3-1. Mine Data (Con't)

## M19 PLASTIC HEAVY ANTITANK MINE

<p>1</p> 	<p>2 Wt ..... 28 lbs. Explosive ..... 21 lbs. Fuze ..... M606 integral (with pressure plate) Secondary fuze wells ... 2 Functioning: 350 to 500 lbs.</p>	<p>5</p>  <p>Screw threaded detonator into detonator well.</p>	<p>6</p>  <p>Place mine in hole, remove safety fork; and turn dial to ARMED.</p>	<p>7</p>  <p>Complete camouflage</p>	<p>8 TO BURY: Put mine in hole with pressure plate at or slightly above ground level.</p>	<p>9 TO DISARM: Remove shipping plug; check position of striker (offset). Remove safety fork, then turn dial to ARMED position. Check fuze position of striker.</p>
<p>1</p> 	<p>2 Wt ..... 28 lbs. Explosive ..... 21 lbs. Fuze ..... M606 integral (with pressure plate) Secondary fuze wells ... 2 Functioning: 350 to 500 lbs.</p>		<p>3</p>  <p>Place mine in hole, remove safety fork; and turn dial to ARMED.</p>	<p>4</p>  <p>Complete camouflage</p>	<p>5 TO BURY: Put mine in hole with pressure plate at or slightly above ground level.</p>	<p>6 TO DISARM: Remove shipping plug; check position of striker (offset). Remove safety fork, then turn dial to ARMED position. Check fuze position of striker.</p>

# M21 METALLIC (KILLER) ANTITANK MINE



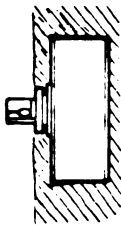
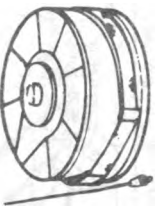
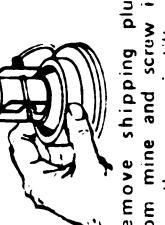

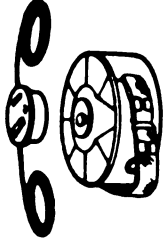


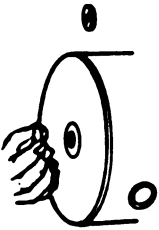


<p>1</p> 	<p>2</p> <p>Wt ..... 18 lbs. Explosive ..... 10.5 lbs. Fuze ..... M607 Functioning ..... 290 lbs. (Pressure on pressure ring or 20° deflection of tilt rod)</p>	<p>5</p>  <p>Remove shipping plug from mine and screw in fuze, then screw in tilt rod extension.</p>	<p>6</p>  <p>Bury mine</p>
<p>3</p>  <p>Remove closing plug, insert M120 booster in bottom, and replace closing plug.</p>		<p>7</p>  <p>Remove safety (pull ring assembly) and complete camouflage.</p>	
<p>4</p>  <p>Remove closure assembly from fuze.</p>		<p>8</p> <p>For pressure type mine bury with fuze cap flush with ground surface. Tilt Rod-mines should be seated firmly in snug-fitting hole. Most effective in tall brush or grass.</p>	
	<p>9</p> <p>TO DISARM: Reverse arming procedure.</p>		

Table 3-1. Mine Data (Con't)

## M21 ANTITANK MINE USED WITH M612 FUZE

<p>1</p> 	<p>5</p>  <p>Bury mine. Cross and extend hoses.</p>
<p>2</p> <p>Has two 2.7m pneumatic leads, safety latch and arming lever.</p>	<p>6</p>  <p>Lift safety latch and turn arming lever to ARMED. Recross hoses.</p>
<p>3</p>  <p>Remove closing plug, insert M120 booster.</p>	<p>7</p>  <p>Complete camouflage.</p>
<p>4</p>  <p>Remove shipping plug</p>	<p>8</p> <p>Timer provides a <math>30 \pm 5</math> minute safe separation period. Both leads must be depressed for initiation.</p>

# M24 OFF-ROUTE ANTITANK MINE

## 1 INSTALLING AND ARMING

### DISPENSER

### POUCH ACCESSORIES POUCH



## 2



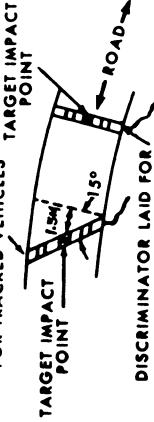
DISCRIMINATOR M61 FIRING ASSEMBLY BIPOD  
ASSEMBLY ON DEVICE SIGHTING ASSEMBLY  
SPOOL

Remove above items from accessories pouch. Insert batteries (issued separately) in firing device.

## 3

DISCRIMINATOR LAID  
FOR TRACKED VEHICLES

TARGET IMPACT  
POINT



DISCRIMINATOR LAID FOR  
WHEELED VEHICLES

Unreel discriminator starting at far side of road (perpendicular to edge for wheeled vehicles; about 15° from perpendicular for tracked vehicles).

## 4

BROWN MARKS

DISCRIMINATOR



FIRING DEVICE



Attach discriminator wire to DETECTOR of firing device (toggle switch on SAFE). Stand on two brown marks on discriminator nearest firing device. If lamp lights, circuit is good; otherwise, discard system.

## M24 OFF-ROUTE ANTITANK MINE (CON'T)

5



Disconnect discriminator wire from firing device. Remove launcher from dispenser pouch and place in position. Remove packing blocks, push rocket forward to safety band, and remove band. Depress ejection pin and push rocket back into launcher until contact ring is exposed at base. Grounding clip must be connected. Remove tagged shorting clip and push rocket back into launcher. Tape plastic covers over ends of launcher.

6



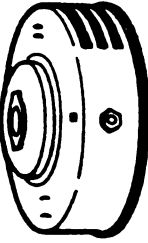


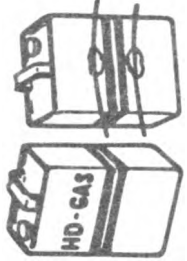
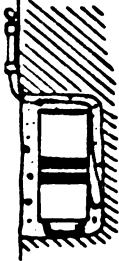
Position launcher on bipod assembly or mound of earth. Mount sighting assembly and sight along discriminator to target impact point about 1m above road (soldier's belt buckle.) To aim, move launcher, not sight. Fill poucher with dirt, lay over launcher, recheck sight, remove sight, re-connect discriminator wire to firing device (light out), connect rocket cable to firing device, and push toggle switch to ARM. The mine is now armed and will explode when the vehicle crosses the road.





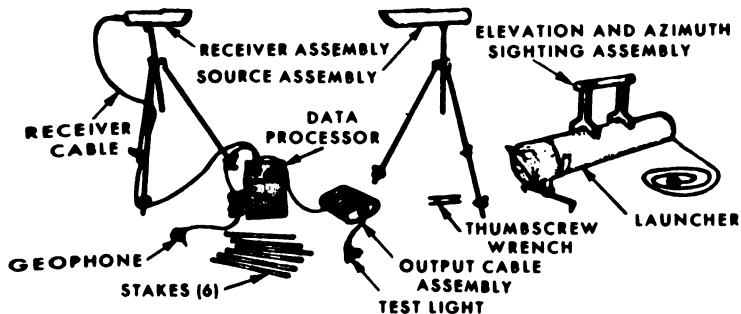
Table 3-1. Mine Data (Con't)

## M23 AND M1 1 GALLON CHEMICAL LANDMINES

<p><b>1</b></p> 	<p><b>5</b></p> <p>Electric Firing</p>  <p>Attach burster charge—1.2m length of detonating cord—to side of mine.</p>
<p><b>2</b></p> <p>When armed for pressure detonation, emplace in same manner as the M15 antitank mine.</p>	<p><b>6</b></p>  <p>Bury mine 10cm and attach detonating cord to controlled firing system.</p>
<p><b>3</b></p> 	<p><b>7</b></p> <p>Nonelectric Firing</p>  <p>Bury mine as above and attach nonelectric detonator to burster.</p>
<p><b>4</b></p> <p>Wt. 11 lb. loaded; has a 1.2m length of detonating cord for burster charge. May be armed for electric.</p>	<p><b>8</b></p> <p><b>WARNING: Soldiers preparing, laying, and removing chemical landmines must wear</b></p>

*Table 3-1 Mine Data (Con't)*

## M66 OFF-ROUTE ANTITANK MINE

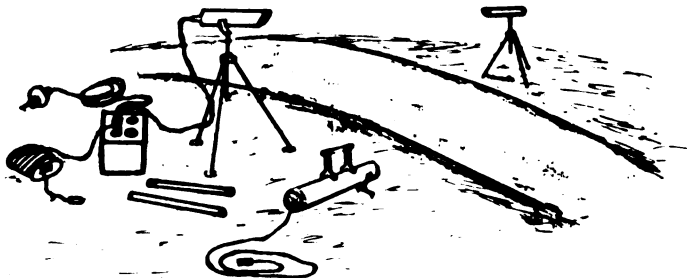


Assemble tripods, source and receiver assemblies. Install battery in source assembly.

Table 3-1. Mine Data (Con't)

## M66 OFF-ROUTE ANTITANK MINE (CON'T)

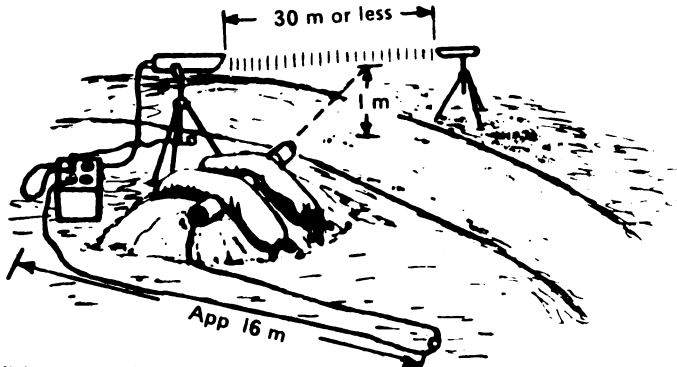
2



Select well camouflaged sites across road. Aim source assembly at receiver and about 1 meter above road center. Stake legs of tripod to ground. Aim receiver at source assembly. Connect Geophone cable, output cable w/test light, and receiver assembly cable to data processor. Install batteries in data processor. Hold Geophone steady and place hand in front of receiver. If test light functions system is operative (If it does not function check connections and source/receiver alignment). Disconnect Geophone and place hand in front of receiver. Test light should not function. If light functions system is inoperative and should not be used). If light does function connect Geophone cable and press spike into ground.

Table 3-1. Mine Data (Con't)

### M66 OFF-ROUTE ANTITANK MINE (CON'T)




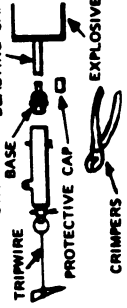



Unwind firing cable from rocket, slide rocket forward from launcher enough to remove safety. Depress ejection pin and slide back into launcher. Position launcher and sight on impact point 1m above road center on source/receiver line. Secure launcher with sandbags. Position output cable and firing cable as shown. Test light should not function. If it does recheck connections and source/receiver alignment. Remove shorting plug and connect cables.

**WARNING:** Make sure all personnel are clear of launcher when testing circuits.

Table 3--1. Mine Data (Con't)

## M1 PULL FIRING DEVICE

<p><b>1</b></p> <p>LOCKING SAFETY POSITIVE SAFETY</p>  <p>INITIATING ACTION: 3 to 5 lb pull on tripwire.</p>	<p><b>4</b></p>  <p>TO DISARM: Insert nail, length of wire or original safety pin in positive safety pin hole first. Then insert similar pin in locking safety pin hole. Cut tripwire, and separate firing device and explosive. Unscrew standard base.</p>	<p>Remove protective cap from standard base and crimp on nonelectric blasting cap. Attach firing device assembly to charge. Attach anchored tripwire.</p>	<p><b>5</b></p>  <p>The M1 pull firing device can be used as an antihandling device on the M15 or M19 AT mines. The arming procedures are the same as above. The device is employed in the side fuze well and a tripwire attached from the M1 to a stake secured underground near the mine.</p>
<p><b>2</b></p> <p>TRIPWIRE STANDARD BASE NONELECTRIC BLASTING CAP PROTECTIVE CAP EXPLOSIVE CRIMPERS</p> 			
<p><b>3</b></p> <p>FIRST LAST</p>  <p>TO ARM: Remove locking safety pin first, and positive safety pin last.</p>			

# M1A1 PRESSURE FIRING DEVICE



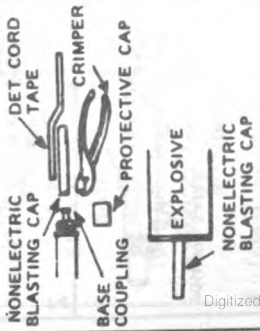




<p><b>1</b></p>  <p>Initiating pressure: 10 lbs or more.</p>	<p><b>3</b></p>  <p>TO ARM: Remove safety clip. Then positive safety pin.</p>
<p><b>2</b></p>  <p>Remove protective cap from base and crimp on nonelectric blasting cap. Assemble det cord, nonelectric blasting cap, and firing device.</p>	<p><b>4</b></p>  <p>TO DISARM: Insert wire, nail, original pin in positive safety hole. Replace safety clip, if available. Unscrew base assembly from firing device.</p>

Table 3--1. Mine Data (Con't)

## M3 PULL-RELEASE FIRING DEVICE

<p><b>1</b></p> 	<p><b>3</b></p>  <p><b>TO ARM:</b> With cord, remove small cotter pin from locking safety pin, and withdraw locking safety pin. If it does not remove easily, adjust winch winding. With cord, pull out positive safety pin.</p>
<p><b>2</b></p>  <p>Remove protective cap and crimp on a nonelectric blasting cap. Attach firing device assembly to anchored charge (must be firm enough to withstand pull of at least 6-10 lbs. pull on tripwire). Put free end of anchored tripwire in hole in winch with knurled knob, draw up tripwire until locking safety is pulled into wide part of safety pin hole.</p>	<p><b>4</b></p> <p><b>TO DISARM: THE M3 IS DANGEROUS TO DISARM. IT SHOULD BE BLOWN IN PLACE.</b></p> <p><b>NOTE:</b> If the device must be disarmed proceed as follows: Insert length of wire, nail or original pin in positive safety pin hole first. Then insert length of wire, nail or original locking pin in locking pin hole. Disassemble tripwire, firing device and explosive.</p>

# M5 PRESSURE-RELEASE FIRING DEVICE

1

**RELEASE  
PLATE**

**SAFETY  
PIN**



**INTERCEPTOR HOLE**

**INITIATING ACTION:**

Lifting 1.59cm or removing restraining weight (5lb or more).

2

**NONELECTRIC  
BLASTING CAP**

**CRIMPER**



**LENGTH**

**10-GAGE WIRE**

**PLYWOOD PRESSURE  
BOARD**

Insert length of 10-gage wire in interceptor hole and holding release plate down, remove safety pin. Replace safety pin with length of No. 18 wire. Assemble cap, firing device and mine.

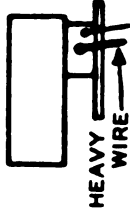
3

**A/T MINE**



**TO ARM:** Remove thin wire (locking safety) and then heavy wire (positive safety) from interceptor hole. **FOLLOW ARMING PROCEDURE CAREFULLY.**

4

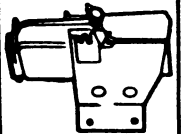
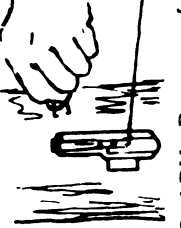

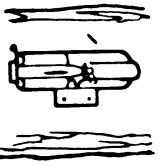
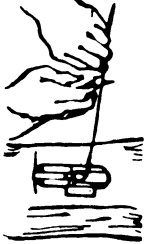
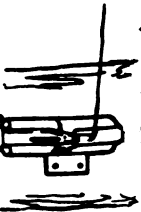


**TO DISARM:** Insert length of heavy gage wire in interceptor hole. Bend wire to prevent dropping out. Proceed carefully, as the slightest disturbance of restraining weight may detonate mine. Disassemble firing device and mine.



Table 3-1. Mine Data (Con't)

**M 49A1 TRIP FLARE**

<p>1</p> 	<p>5</p>  <p>TO ARM: Remove safety clip.</p>
<p>2</p> <p>Burning period ..... 55 to 70 sec</p> <p>Illumination radius ..... 300m</p> <p>Initiated by taut or loose tripwire.</p>	<p>6</p>  <p>TO DISARM: Insert safety pin.</p>
<p>3</p>  <p>Attach flare to post, tree, etc.</p>	<p>7</p>  <p>Check both ends of tripwire and cut near trigger.</p>
<p>4</p>  <p>Attach tripwire to anchor. Tripwire must be taut.</p>	<p>8</p> <p><b>WARNING: Never look directly at burning flare.</b>  <b>Note: For loose tripwire, attach tripwire to anchor.</b></p>

(3) *Point minefield.* Used to delay and disorganize the enemy or to hinder his use of key areas. Generally irregular in size and shape, ranging from a single group of mines to successive mined areas. Both conventional and scatterable mines may be employed. Authority to lay is division — can be delegated to brigade.

(4) *Interdiction minefield.* Used in the enemy rear to harass and disrupt normal activities, and to deny the enemy the use of key facilities. Normally consists of scatterable mines. Authority to lay is corps — can be delegated to division.

(5) *Phony minefield.* Used as part of a barrier system to deceive the enemy when the lack of time, personnel, or material prevents the use of real mines. Effectiveness depends upon resemblance to the type of minefield being simulated. They are of no real value until the enemy has become mine conscious. Authority to lay is the same as the type of minefield being simulated.

*b. Employment*

(1) All minefields should be covered by fire.

(2) Minefield effectiveness can be increased by varying types of mines, fuzes, and tripwires.

(3) Warning devices such as sensors, tripwires, smoke or flame devices, and noise makers should be used to alert troops to enemy breaching attempts.

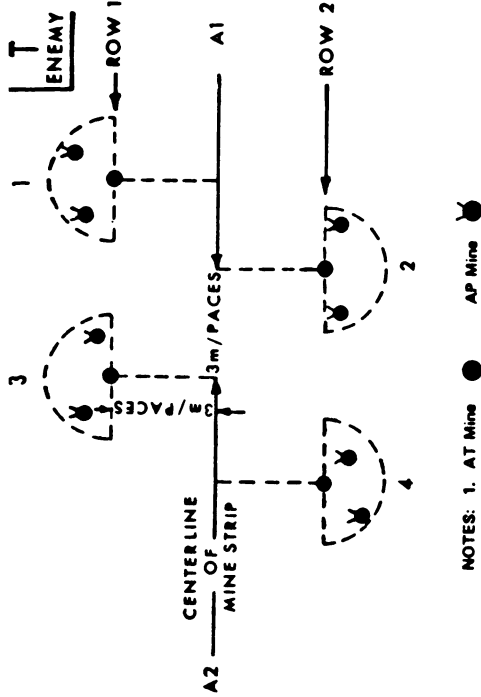
### 3-3. MINEFIELD PATTERNS

*a. Standard Minefield Pattern.* The standard minefield pattern is a defined regular pattern which provides optimum effectiveness against enemy passage and/or breaching. It also allows for ease of removal by friendly troops (fig. 3-1).

(1) *Strip centerline.* A measured, predetermined line along which no mines are placed. It is paralleled on each side by two rows of mines or clusters at a distance of 3 meters (fig. 3-2).

(2) *Row.* A single row of mines or clusters laid in a generally straight line. Mine rows parallel the strip centerline at a distance of 3 meters (or paces) and are laid at 6 meter (or pace) intervals. (fig. 3-2)

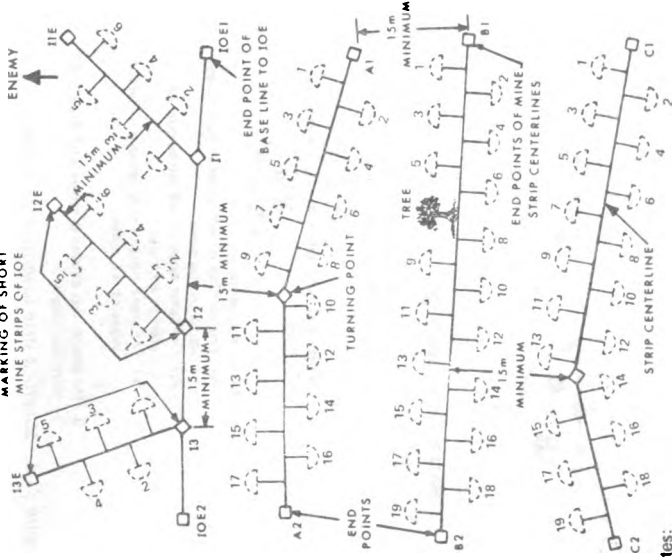




- NOTES: 1. AT Mine      ●      AP Mine
- Cluster with AT mine and 4 AP mines within 2m/pace sem-circle.
  - Cluster with AP base mine and 4 additional AP mines.
  - Within a mine strip:
    - The number of AP mines in each cluster must be the same.
    - Different types of AP mines may be used in a cluster.
    - Different clusters may contain different types of AT mines.
  - No cluster can exceed 5 mines with only 1 AT mine per cluster.

Figure 3-2. Minefield strip with strip centerline, rows, and clusters.

# MARKING OF SHORT MINE STRIPS OF JOE



Notes:

1. Marking of end points with A1 and A2, for example, will indicate laying direction of a minefield.
2. Laying will always begin at point No. 1.
3. Odd numbers on enemy side of the strip.
4. Strip start and end points, and turning points will be marked with a 2" x 2" wooden stake.

Figure 3. 3. Method of numbering clusters in a minefield

CLUSTER AFTER THE TURNING POINT WILL HAVE A DISTANCE OF 3 METERS/PACES FROM THE TURNING POINT AND ARE LAID ON OPPOSITE SIDES OF THE STRIP CENTERLINE.

AN OMITTED CLUSTER IS NUMBERED WHEN IT IS NECESSARY TO MAINTAIN THE NORMAL NUMBERING SEQUENCE AND OMITTED CLUSTERS SO NUMBERED MUST BE NOTED IN THE "NOTES" SECTION OF THE MINEFIELD RECORD (DA FORM 1285).

IF THE DISTANCE IS LESS THAN 3 METERS/PACES BETWEEN THE LAST POSSIBLE CLUSTER AND THE TURNING POINT THE CLUSTER WILL BE OMITTED.

THE FIRST CLUSTER AFTER THE TURNING POINT WILL BE LAID ON THE OPPOSITE SIDE OF STRIP CENTERLINE FROM THE LAST LAID CLUSTER AND THREE METERS/PACES FROM THE TURNING POINT

FIRST CLUSTER OF STRIP WILL NOT BE CLOSER THAN 2 METERS TO THE LINE JOINING THE END POINTS OF MINE STRIPS.

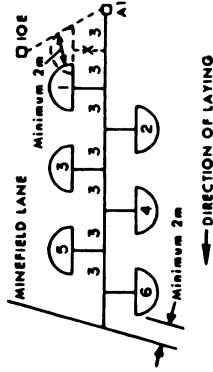
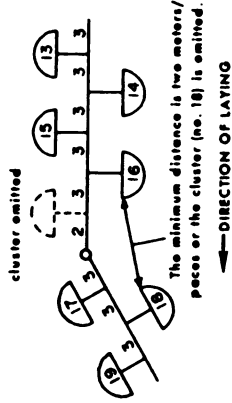
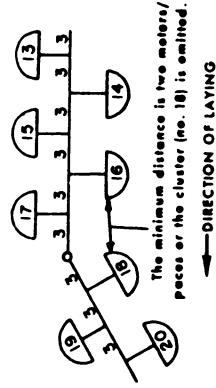


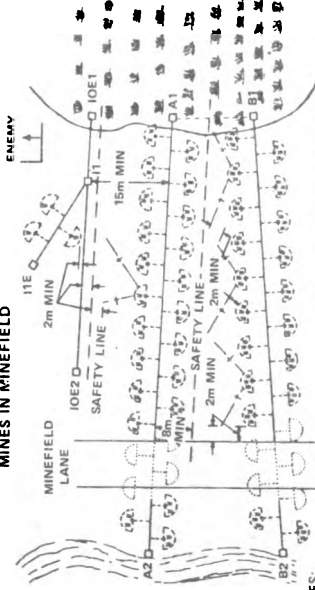
Figure 3-4. Turning points on a minefield strip.

(7) *Minefield gap.* A cleared area through a minefield wide enough for the passage of a friendly force in tactical formation. Width of a minefield gap is seldom less than 100 meters.

(8) *Minefield lane.* A cleared path through a minefield for passage of troops (2 meters wide) or vehicles (8 meters wide — one-way, 16 meters wide — two-way).

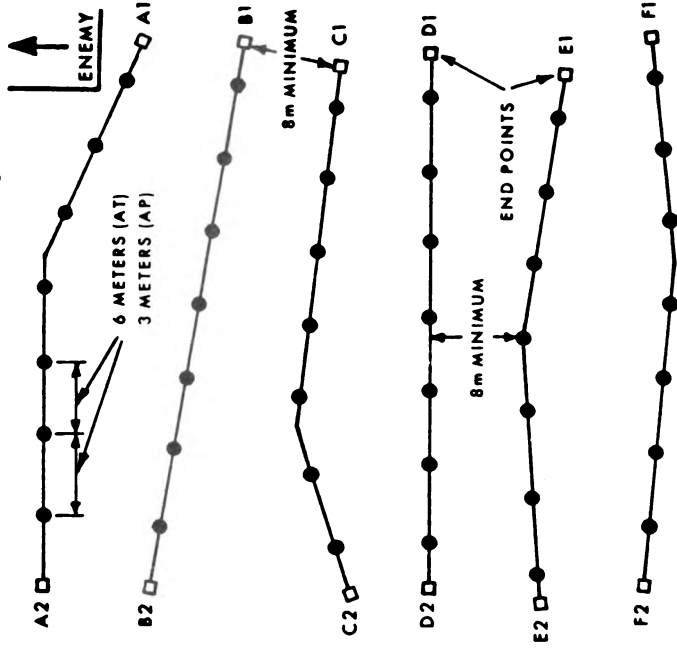
(9) *Tripwires.* Tripwires are employed only with APF mines. Employment procedures are defined in figure 3--5.

**SAFETY LINE AND SAFETY DISTANCES  
REQUIRED WHEN USING WIRE ACTUATED  
MINES IN MINEFIELD**



**NOTES:**

1. - + - = TRIPWIRE EMPLOYED ON MINE ROW ON ENEMY SIDE OF STRIP, ONLY!
2. TRIPWIRE LENGTH WILL NOT EXCEED THE CASUALTY RADIUS OF THE MINE.
3. NO TRIPWIRES IN THE IOE.
4. ONLY ONE MINE PER CLUSTER WILL EMPLOY A TRIPWIRE. (FOR SAFETY PURPOSES IT IS RECOMMENDED THAT THE MINE CLOSEST TO THE ENEMY BE TRIPWIRED. BASE MINE OF CLUSTER SHOULD NOT BE TRIPWIRED.)
5. TRIPWIRES =  $\leq$  2 PER MINE.
6. TRIPWIRES WILL BE EMPLOYED NO CLOSER THAN EVERY THIRD CLUSTER.
7. TRIPWIRES WILL BE ANGLED TOWARD THE ENEMY AND WILL BE NO CLOSER THAN 2 METERS TO ANOTHER TRIPWIRE, ANOTHER CLUSTER, THE SAFETY LINE, THE IOE, MINELANE LINE OR GAP, OR THE MINELANE BOUNDARY.



#### NOTES

Distances may vary according to the tactical objective, the technical effectiveness desired and the characteristics of the mines used, but should remain the same within one mine row.

Figure 3-6. Row mining.



## Section II. MINEFIELD INSTALLATION

### 3-4. MINE AND MAN-HOUR COMPUTATIONS

Material and manpower requirements and logistical and planning data are found in tables 3-2 and 3-3.

*Table 3-2. Mine and Man-Hour Computations and Strip Cluster Composition  
(Sample Problem)*

#### I SITUATION

Desired Density .....	AT a. 1	Apers Frag b. 4	Apers Blast c. 8
-----------------------	---------	--------------------	---------------------

IOE Representative Cluster .....	AT a. 1	Apers Frag b. 2	Apers Blast c. 2
----------------------------------	---------	--------------------	---------------------

#### Meters of Front 200

*Note 1.* If using paces as the unit of measurement, adjust the density by multiplying by 0.75. (Round each figure obtained up to the next whole number.) Then convert the front to paces by multiplying the front, in meters, by 1.34.

*Example:* Desired density of mines/meter of front is 1-4-8.

Desired density using paces

$$1 \times .75 = \text{round up to } 1$$

$$4 \times .75 = 3$$

Desired front using paces

$$200 \times 1.34 = 268 \text{ paces}$$

Adjusted density is 1-3-6

*Note 2.* If paces are used as the unit of measure, you must use the *adjusted density* and the front, in *paces*, in your calculations.

## II MINE COMPUTATION

*NOTE:* This example is computed using meters as unit of measure.

- (1) Meters of front divided by 9 equals the approximate number of IOE Clusters.

$$\frac{200}{9} = 22.2 \text{ (round up to 23)}$$

- (2) Multiply the number of IOE clusters (line 1) x IOE representative cluster (1-2-2).

a. 23      b. 46      c. 46

- (3) Meters of front x desired density, if installing in meters (or paces of front x adjusted density, if installing in paces) = mines in minefield.

a. 200      b. 800      c. 1600

- (4) Add line 2 and line 3 (subtotal of mines).

a. 223      b. 846      c. 1646

- (5) Compute 10% of line 4 for mine rejections, and strip length variances (round up).

a. 23      b. 85      c. 165

Table 3-2. *Mine and Man-Hour Computations and Strip Cluster Composition (Sample Problem) (Continued)*

- (6) Add line 4 plus line 5 = total mines needed.
- a. 246      b. 931      c. 1811
- (7) Divide total mines needed (by type) by laying rate figures.

AT: 4 mines/hour/man

APF: 8 mines/hour/man

APB: 16 mines/hour/man

Then take sum of man-hours of all three types and multiply by 1.2 to obtain total installation man-hours (includes marking, siting, and recording).

EXAMPLE:

$$\frac{246}{4} = 62$$

$$\frac{931}{8} = 117$$

$$\frac{1811}{16} = 114$$

293 Total

$$\begin{array}{r} 293 \\ \times 1.2 \\ \hline \end{array}$$

352 Total Man-Hours Required\*

\*This figure is only work time. If working in darkness, multiplying by 1.5.

(8) Add a + b + c of desired (or adjusted) density.

$$\frac{3}{5} \times \frac{13}{1} = \frac{39}{5} = 7.8 \text{ (round up to 8)}$$

(10)  $3 \times \text{AT density } (3 \times 1) = 3$

(11) Number of strips (highest from line 9 or 10) = 8.

(12) Desired density  $\times 3$  (by type) gives total needed to maintain that density.

$$\text{AT: } 3 \times 1 = 3$$

$$\text{APF: } 3 \times 4 = 12$$

$$\text{APB: } 3 \times 8 = 24$$

(13) Distribute total from line 12, as desired, between lettered strips needed (line 11) to get strip cluster composition.

Given	IOE	AT	APF	APB	Total across (max 5)
	A	1	1	3	5
	B	0	2	3	5
	C	0	1	3	4
	D	1	1	3	5
	E	0	2	3	5
	F	1	1	3	5
	G	0	2	3	5
	H	0	2	3	5
	Total **	3	12	24	

\*\* same as line 12

Table 3. 2. Mine and Man-Hour Computations and Strip Cluster Composition  
(Sample Problem) (Continued)

MINEFIELD LOGISTIC RULES OF THUMB:

- (1) *Fence Trace.* Formula for fencing 4 sides (meters) one strand.  
 $[2.0 \text{ (depth)} + 2.0 \text{ (front)} + 160 \text{ meters}] \times 1.40 = \text{total length of fence (meters)}$
- (2) If using a two-strand fence, multiply by two to obtain meters of wire required.
- (3) *Pickets.* 
$$4 \text{ sides: } \frac{\text{total length of fence (see 1 above)}}{15} = \text{number of pickets required.}$$
- (4) *Mine signs.* The number of signs (4 sides of minefield fenced) equals the number of pickets.
- (5) *Engr tape.* Comes 170 (M)/roll. Used for:
  - (a) Boundaries
  - (b) Strip centerlines (incl IOE short strips)
  - (c) Lanes
  - (d) Gaps
  - (e) Tripwire safety lines
- (6) *Sandbags.* (Avg 3/Cluster) (Used for removal of spoil.)
  - Step 1. Number of IOE clusters  $\times 3$ .
  - Step 2. Number of lettered strips  $\times$  answer obtained in Step 1.

Step 3. 3 x answer obtained in Step 2.

Step 4. Add answer from Step 1 and Step 3.

(7) 2" x 2" x 12" wood stakes. Used:

(a) Right and left end points of mine strips

(b) Each turning point

(c) Beginning and end points of IOE short strips

Table 3-3. Mine-Carrying Capacity of Military Vehicle.

TYPE MINE	2½ T CGO	2½ T DMP	5 T DMP	1½ T TRL
M15	103	56	90	61
M19	126	80	196	74
M21	224	160	192	132
M14	10,260	4,320	6,480	6,120
M16A1	448	320	672	264
M18A1	1,165	480	1,260	700
M24	1,260	900	1,440	774
M25	12,000	6,720	9,216	7,200

Note. Figures shown are for crated mines only.

### 3-5. MINEFIELD MARKING

- a. *Marking Location of Minefield.* Minefields are marked (normally fenced) according to the tactical situation to protect friendly personnel from inadvertently entering a minefield. Marking usually consists of a standard two-strand fence with signs indicating mines. Marking is also used to mark lanes or gaps in a minefield. See figures 3-7, 3-8, and 3-9. The U.S. minefield marking set contains components for marking a safe lane 400 meters through a minefield.

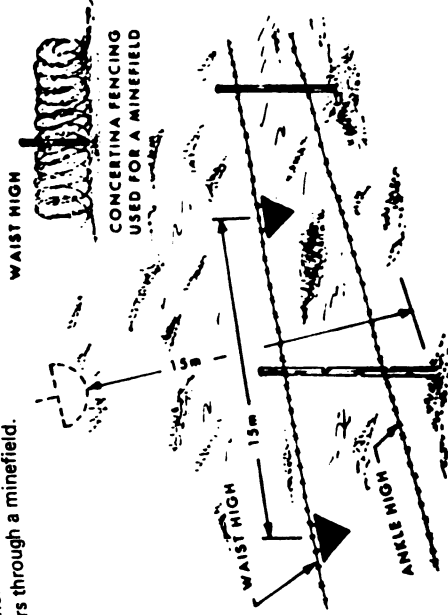


Figure 3-7. Minefield marking fence.

- b. *Marking and Referencing Mine Strips.* The beginning and end of each mine strip and all turning points in the strip are marked with wooden stakes or pickets driven flush with the ground. When available, nails should be driven into each stake to enable the metallic mine detector to find the stake. Beginning and end points are identified with alphabetic characters (e.g., A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z).

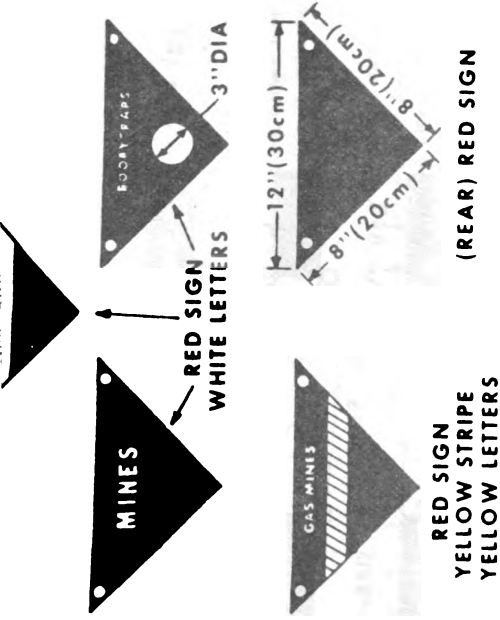


Figure 3-8. Standard marking signs.

### 3-6. ORGANIZATION OF MINELAYING UNIT

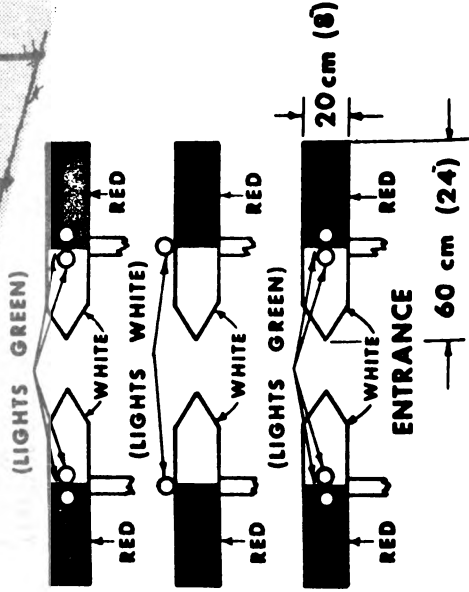
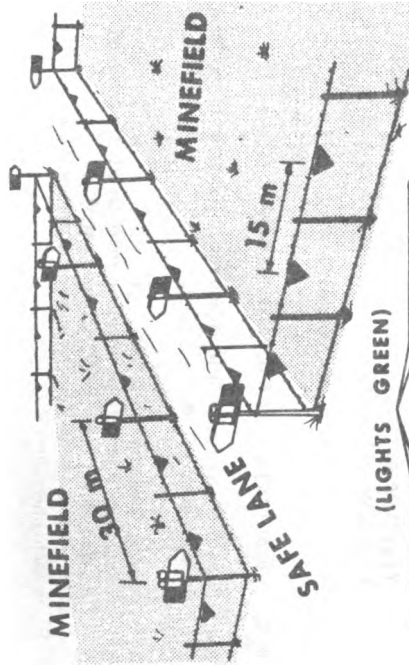
*a. Platoon Organization.* The organization and duties of members are listed in table 3-4.

*b. Safety.* See paragraph 3-14.

*c. Camouflage.* Camouflage discipline must be strictly enforced (i.e., dispersion of men, vehicles, mine dumps).

*d. Mine Dumps.* Mine dumps should be located no closer than 150m to each other.





Personnel	Officer	NCO	EM	Equipment
Supervisory personnel	1	1		Officer: Map, lensatic compass, notebook, and minefield record forms.  NCO: Map, notebook, and lensatic compass.
Siting party		1	3	Stakes or pickets, sledges, hammers, tracing tape on reels, and nails to peg tape.
Marking party		1	2	Barbed wire on reels, marking signs, lane signs, wire cutters, gloves, sledges, pickets.
Recording party		1	2	Sketching equipment, lensatic compass, minefield record forms, map, and metric tape.
1st laying party		1	6 to 8	Notebook for squad leader, picks, shovels, and sandbags.
2nd laying party		1	6 to 8	Same as 1st laying party.
3rd laying party		1	6 to 8	Same as 1st laying party.
Total	1	7	25 to 31	

NOTE: Organization may vary depending on terrain, men, and materials available and the proximity of the enemy.

### Section III. REPORTING AND RECORDING

#### 3-7. MINEFIELD REPORTS

A minefield report is any message or communication, either oral or written, concerning either friendly or enemy mining activities. Reports of friendly minefields are classified and will be transmitted by some secure means.

*a. Mandatory Minefield Reports.*

- (1) *Report of intention to lay (table 3-5)*
- (2) *Report of initiation of laying*
- (3) *Report of completion of laying (table 3-6)*

*b. Additional Reports (submit as needed).*

- (1) *Progress reports*
- (2) *Report of transfer*
- (3) *Report of change*
- (4) *Enemy minefield report (table 3-7)*

#### 3-8. MINEFIELD RECORDS

*a. DA Form 1355.* This form is used to record all minefields except the hasty protective minefield. DA Form 1355 consists of a single printed sheet. The front consists of an upper half for tabular data and a lower half for a scale sketch of the field. On the reverse side are instructions for completing the DA Form 1355 and a form for computing the number of mines. When completed, the DA Form 1355 is classified SECRET. When used for training purposes, the word SECRET must be crossed out and the word SPECIMEN printed on the form in each place the word SECRET appears. (See figs. 3-10 through 3-12). When properly completed the DA Form 1355 should be clear enough to facilitate minefield removal by other units.

Explanation	Letter designation	(1)a
Tactical Objectives (Temporary Security Roadblock or Other).	ALPHA	Bridge Work Site Security
Type of Minefield	BRAVO	Hasty Protective
Estimated number and types of mines and whether surface laid mines or mines with antihandling devices	CHARLIE	10 ea. M18A1 No A.H.D.
Location of Minefield by Coordinates	DELTA	UT 0976
Location and Width of Minefield Lanes and Gaps	ECHO	Rt. 67 No. --- So. Approach to Bridge
Estimated Starting and Completion Date/Time/Group	FOXTROT	Start 190700 May 74 Completion 190800 May 74

- a. First minefield in report.  
b. Additional minefields in report.

Table 3-6. Report of Completion of Minefield w/Example

Explanation	Letter designation	(1)a	(2)b (3)b
Changes in Information Submitted in Intention to Lay Report	ALPHA	None	
Total Number and type of AT and Apers Mines Laid	BRAVO	M15-299 M26-865 M14-601	
Date and Time of Completion	CHARLIE	231800 Mar 72	
Method by Laying Mines (Buried, by Hand, by Machine)	DELTA	Buried by Hand	
Details of Lanes and Gaps Including Their Marking.	ECHO	WD1 wire on G AZ. 270° Ent & Ex marked w/2U pickets	
Details of Perimeter Marking	FOXTROT	Standard fence	
Overlay Showing Perimeter, Lanes, and Gaps	GOLF	N/A	
Laying Unit and *Signature of Individual Authorizing Laying of the Field.	HOTEL	2d Plt, Co "A", 546th Engr Bn (C)	

Explanation	Letter designation	(1)a°	(2)b°	(3)b°	(4)b°
Map Sheet(s) Designation	ALPHA				
Date and Time of Collection of Information	BRAVO				
Type of Minefield (AT, Apers)	CHARLIE				
Coordinates of Minefield Extremities	DELTA				
Depth of Minefield	ECHO				
Enemy Weapons or Surveillance	FOXTROT				
Estimated Time to Clear Minefield	GOLF				
Estimated Material and Equipment required to Clear Minefield	HOTEL				
Routes for Bypassing the Minefield, if any	INDIA				
Coordinates of Lane Entry	JULIETT				
Coordinates of Lane Exit	KILO				
Width of Lanes (Meters) C°	LIMA				
Other, Such as Type of Mines New Mines or Boobytraps	ZULU				

**\*NOTES:**

- a. First minefield in report.
- b. Additional minefields in report.
- c. Additional lanes or/and gaps are reported under an extended alphabetical listing.

b. *DA Form 1355-1-R, Hasty Protective Minefield Record.* The purpose of the Hasty Protective Minefield Record form is to insure the proper recording of any hasty protective minefields laid by detached or isolated units. The form is issued down to and including platoons. It does not replace the current minefield record, DA Form 1355. The Hasty Protective Minefield Record is unclassified as long as the minefield is temporary in nature. However, when the field is declared a deliberate protective field or incorporated into a larger field, it must be classified SECRET and the information transferred to the DA Form 1355. The reverse side of the Hasty Protective Minefield Record (DA Form 1355-1-R) consists of full instructions to the recorder and an example of a recorded minefield.

c. *Enemy Minefield Record.* The standard DA Form 1355 is used when preparing a record of an enemy field. The record should include a full description of the marking and a sketch or overlay showing location and other information. The record must be marked at the top with the words ENEMY MINEFIELD.

#### Section IV. REMOVAL OF MINES

### 3-9. CLEARING MINED AREAS

#### a. *Detection Methods.*

- (1) Visual.
- (2) Probing.
- (3) Dogs.
- (4) Mine Detectors. Both types of detectors, metallic and nonmetallic, may give signals when items other than mines are detected. Experience in operating each type enables the user to recognize the characteristics of the signal to be expected from each type mine. Since this is a very exacting task, no individual should be permitted to operate a detector for more than 20 minutes at a time.

b. *Mine Removal.* The following methods are used to remove or neutralize mines. These are listed in relative order of use. Where possible, hand neutralization will be avoided.

- (1) Explosives.
- (2) Fuses and hooks.





**Figure 3-10b. Standard detailed minefield record (DA Form 1355) (bottom half, front).**

1998, 2005, 2010

### MINEFIELD RECORD

1998, 2005, 2010

SPECIMEN

71

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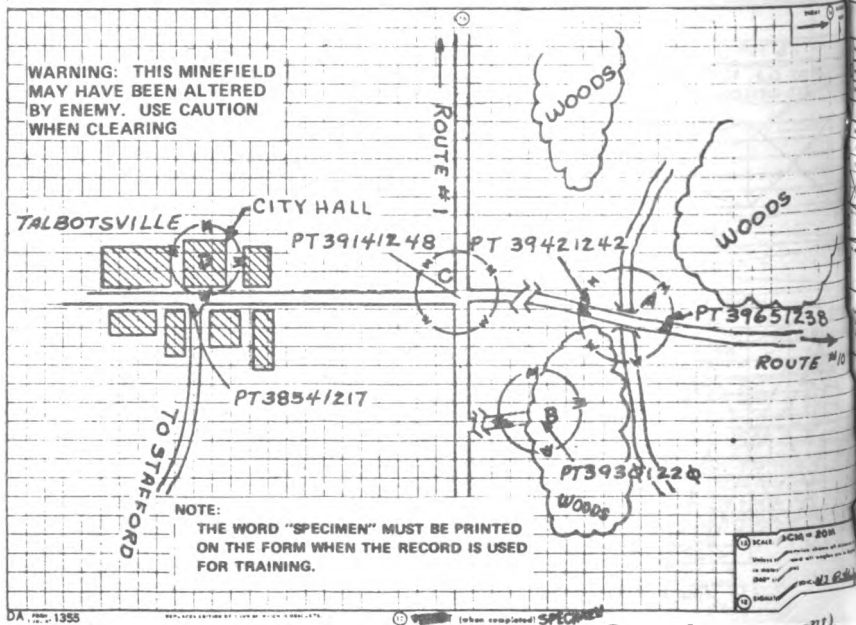


Figure 3-11b. Record of point minefield with minimum information (bottom half, fr

(When completed)

## MINEFIELD RECORD

(FM 30-32)

SPECIMEN

Location: **C.G. 8 x X (INF)****3 PLT, Co "A", 54<sup>TH</sup> ENGR BN**Target: **2LT. JERRY D. WILLIAMS 135-45 428**

Date &amp; Time

Start: **071100 MARCH 1975**Completion: **072000 MARCH 1975**Recorder: **SGT. M.B. DAVIS 307-286-1943**Map grid No. **8XX(INF)-1E**Type **POINT**Map Name and Scale **TALBOTVILLE 1:50,000**Sheet No. or Name **721**

## LANDMARKS

Coordinates	Description
UT1826777B	BRICK CHURCH BUILDING N.W. CORNER
UT1827177I	EAST SIDE ROAD INTERSECTION

If necessary, record at 100 meters

Position: **4** Description of Strip/Group Markers**US**

## IMPERVIOUS TO MINING REFERENCE STAKE

No.	Description
1	U-SHAPED PICKET EX-LONG 3M RAPS WHITE ENGR. TAPE
2	
3	

## LANES

No.	Width	How Marked	Provisions for Closing
1			
2			
3			

## ANTI-TANK MINES

## ANTI-PERSONNEL MINES

Type	Type	Type	Total AT Mines	Anti-Handling Barriers	Type	Type	Type	Type	Total AP Mines
No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
7			7						
7			7						
7			7						
7			7						
28			28						

## NOTES

1. ALL MINES EQUIPPED WITH OUTTRIGGERS.
2. ALL MINES ARE WATER RESISTANT TREATED.
3. ALL SAFETIES BURIED  $\frac{1}{3}$  METER SOUTH OF REFERENCE STAKE.
4. AVERAGE DEPTH OF STREAM IS ONE METER.
5. ARROWS SHOW DIRECTION AZIMUTHS WERE TAKEN.
6. MINES ARE NUMBERED IN SEQUENCE THEY WERE INSTALLED.
7. CLUSTERS OMITTED, NONE.

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e 3-12a. Record of mines implaced in a ford deeper than 0.6 meters (top half, front).

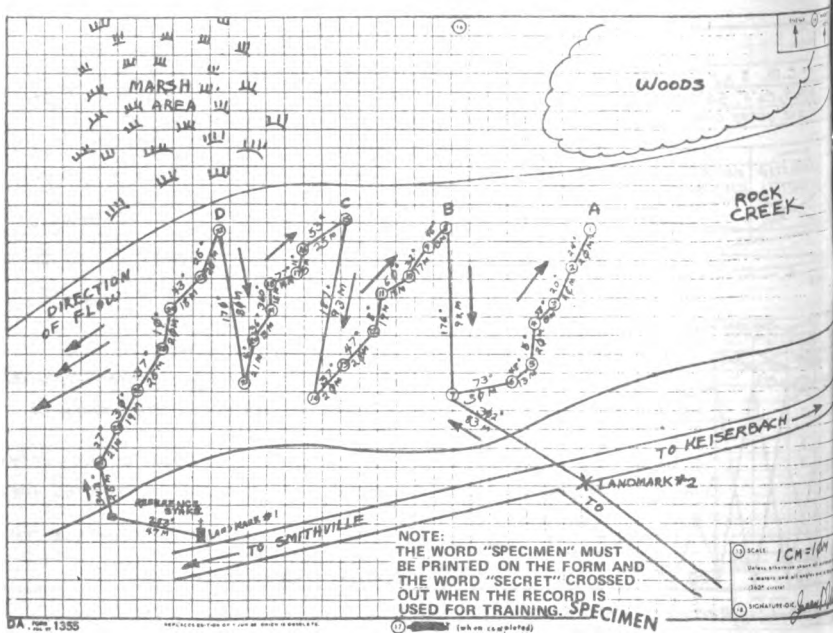


Figure 3-12b. Record of mines implaced in a ford deeper than 0.6 meters

A hasty breach operation is performed when the tactical situation requires maintaining the momentum of an attack. It will result in a safe lane through a mined area. Two methods of hasty breaching are:

a. *Bangalore Torpedo Train*. Two-inch diameter by 1.5-meter-long sections. Pushed into obstacle by hand or propelled by rocket motor. Clears a narrow footpath. For detailed information see TM 9-1375-213-12.

b. *Demolition Kit Projected Charge M157*. Approximately 7 inches high, 12 inches wide, and 400 feet long. Weight — 11,000 pounds. Pushed or towed by medium tanks. Detonated by impact fuze. In most soils, it creates a crater approximately 320 feet long, 12 to 16 feet wide, and 3 to 5 feet in depth. For detailed information see TM 9-1375-204-10.

### 3-11. DELIBERATE BREACH OPERATIONS

Deliberate breach operations are carried out by manual methods with mine detectors and/or probes (fig. 3-13 and table 3-8).

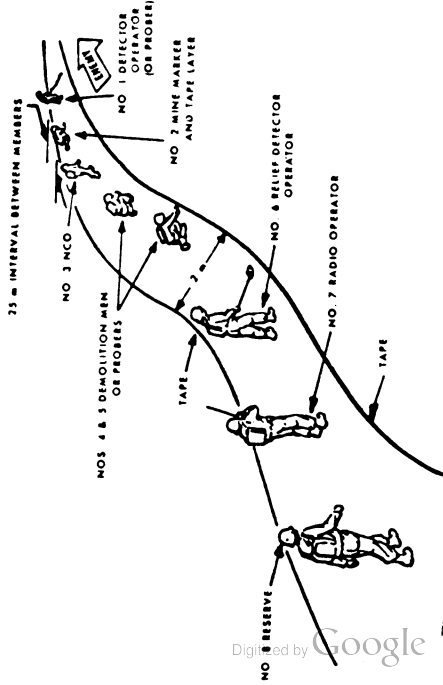


Figure 3-13. Deliberate, manual, minefield breaching party.

Table 3-8. Platoon Organization and Equipment for Manual Breaching

Personnel	Officer	NCO	EM	Equipment
Officer in Charge	1			Lensatic compass, map, radio, and individual weapon.
Platoon Sergeant		1		Same as OIC, except without radio.
No. 1 Breaching Party		1	7	Two portable detectors, two probes, mine markers, marking tape or wire on reels, safety pines, clips, smooth wires (18" lengths) ½-lb blocks of explosives, blasting caps, detonating cords, safety fuze, fuze lighters, crimpers, and portable radio.
No. 2 Breaching Party		1	7	Same as No. 1 breaching party.
No. 3 Breaching Party		1	7	Same as No. 1 breaching party.
Support Party		1	10	Same as No. 1 party, plus: sledges or mauls, hammers, pliers, wire cutters, 2" by 4" stakes at least 6' long, individual weapons, litters, lane-marking signs, gauntlets, barbed wire, stakes, and pickets.
Totals	1	5	31	

### 3-12. AREA CLEARING OPERATIONS

- a. Manual method with mine detectors and/or probes (fig. 3-14 and table 3-9).
- b. Friendly fields. By use of minefield record.
- c. Route clearance (fig. 3-15).
- d. Helicopter L.Z. clearance (fig. 3-16).
- e. Average breaching/clearing time and material requirements (table 3-10).

#### THE 25 - METER INTERVAL BETWEEN DETECTOR PARTIES PREVENTS ELECTRICAL INTERFERENCE BETWEEN DETECTORS AND HELPS TO REDUCE CASUALTIES FROM MINES

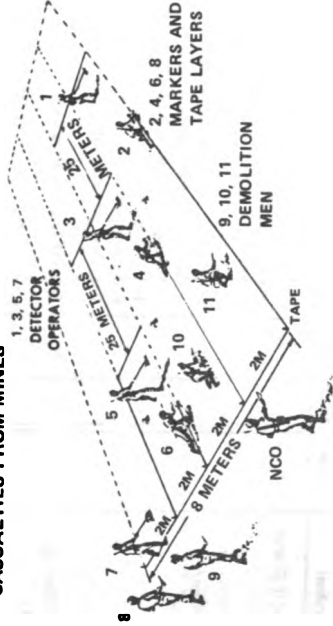


Figure 3-14. Clearing party using electronic detectors.



Table 3-9. Platoon Organization and Equipment for Manual Clearing

Personnel	Officer	NCO	EM	Equipment
Officer in Charge	1			Map, lensatic compass, portable radio, and all available information on mines in area.
No. 1 Clearing Party		1	10	Mine probes, tracing tape on reels, mine markers, grapnels, rope, or wire in 50-meters lengths, 18-in. lengths of 10- and 16-gauge wire, demolition equipment, shovels or entrenching tools, and portable radios.
No. 2 Clearing Party		1	10	Same as No. 1 clearing party.
No. 3 Clearing Party		1	10	Same as No. 1 clearing party.
Control Party		1	2	Map, lensatic compass, portable radio (2 preferably, 1 for platoon and for company net).
Totals	1	4	32	

## 3-13. TACTICAL EMPLOYMENT OF CLAYMORE MINE M18A1

a. *General.* The CLAYMORE is primarily a defensive weapon which may be directionally sighted to provide fragmentation over a specific area. The major advantage of the CLAYMORE is that it is adaptable to controlled detonation and does not rely solely upon chance detonation by the enemy. The CLAYMORE is particularly suitable for use in the hasty protective

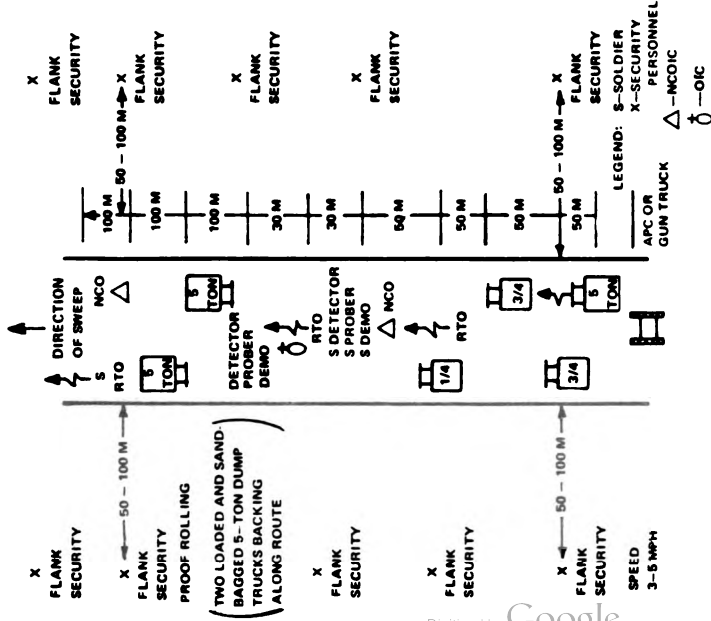
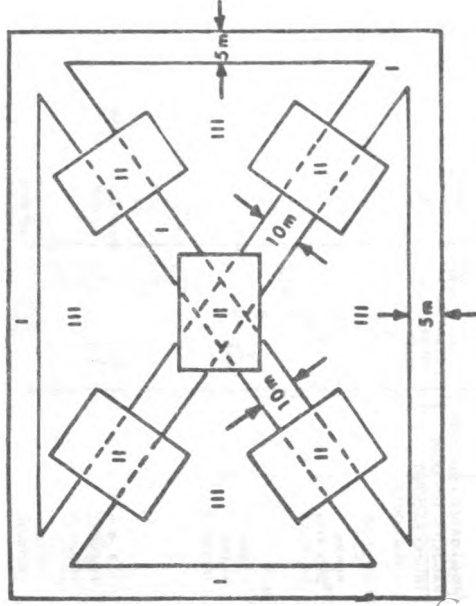


Figure 3-15. Typical sweep team formation.

# HELIPORT CLEARING METHOD



- I = PHASE I CLEARANCE. TWO 10 METER WIDE DIAGONALS AND A 5 METER WIDE PERIMETER STRIP.**
- II = PHASE II CLEARANCE. FIVE HELICOPTER PADS.**

**Note:** The size of and distance between landing pads should be determined by coordination with the aviation unit which will use the heliport.

Method	Width of cleared lane (in meters)	Man-hours req'd per 100 meters	Remarks
<b><u>MANUAL</u></b>			
Location by probing	1 (footpath)	16-22	See note.
Removal by rope or explosives	1 (footpath)	38-44	See note.
Location by detector, assisted by probing	8 (one-way vehicle lane)	27-33	See note.
Removal by rope or explosives	8 (one-way vehicle lane)	220-247	See note.
<b><u>EXPLOSIVES</u></b>			
Demolition snake M157 Diamond Lil)	4.0-6.0	6-8*	6 to 8 man-hours to assemble
Bangalore torpedo	1 (footpath)	3.5-4.5	See note.

*NOTE:* Based upon average conditions of visibility and moderate enemy activity and normal U.S. countermeasures; i.e., screening of enemy observation and counter-battery fires against hostile artillery or other weapons covering the field.

\*Per 90 meters (set is only 90 meters long.)

*b. Defensive Uses.*

- (1) To cover the range between maximum hand grenade throwing distance and the minimum safe distance of mortar and artillery supporting fire.
- (2) To supplement other minefields when equipped with tripwires.
- (3) To fill the dead space of the final protective fires of automatic weapons in defensive positions.
- (4) To provide security of outposts, command posts, halted columns, etc.
- (5) To cover roadblocks and obstacles.
- (6) To cover retrograde operations.

*c. Offensive Uses (ambushes)*

- (1) Laterally along the killing zone.
- (2) At the front and rear of the killing zone.
- (3) Laterally along the killing zone on the far side of the killing zone from the ambush element. This method is particularly effective in countering enemy immediate action that includes maneuver or withdrawal from the killing zone. *Care must be taken to insure the ambush element is protected from fragmentation.*

*d. Safe Distances.* See table 3-1.

### 3.14. SAFETY PRECAUTIONS

*a. Personnel in a minefield will:*

- (1) Remain dispersed.
- (2) Not run.
- (3) Move only in cleared areas.
- (4) Move to assist injured personnel only when told to do so by unit officers or noncommissioned officers.

*b. All areas or facilities are suspect and are carefully investigated.*

*c. Cleared areas are distinctly marked.*

*d. All mines are considered to be equipped with antihandling devices until proven otherwise. Never uncover a mine until the ground on top has been thoroughly checked for antihandling devices.*

mines, fuzes, and firing devices.

*g.* Mines that are removed are completely separated from fuzes and firing devices and stored separately.

*h.* Rapid means of communication should be maintained to insure maximum control and prompt evacuation of any wounded personnel. Medical aid personnel should be close at hand to accomplish any needed first aid.

*i.* *All minefields are reported and recorded no matter what the size or type of hardware used. One mine, placed in front of an outpost, is a minefield.*

## CHAPTER 4

## FIELD FORTIFICATIONS

## Section I. GENERAL DATA

## 4-1. PRIORITY OF TASKS

The tasks involved in organizing a defensive position are carried out concurrently, but the situation may require that priority be attached to some. The unit commander specifies the sequence for the preparation of the positions with as many tasks being accomplished simultaneously as possible. The normal sequence of tasks is:

- a. Establish security.
- b. Position weapons.
- c. Clear fields of fire, remove objects, mask observation, and determine ranges to probable target locations.
- d. Prepare weapons emplacements and individual positions to include overhead cover and camouflage.
- e. Provide for signal communications and observation systems.
- f. Emplace obstacles.
- g. Prepare routes for movement, supply, and evacuation.
- h. Improve primary positions to include protection from CBR attack.
- i. Prepare deceptive installations in accordance with plans of higher headquarters.

## 4-2. CLEARING FIELDS OF FIRE

a. *Principles.*

- (1) Excess or careless clearing will disclose firing positions.
- (2) In areas organized for close defense, clearing should start near the position and work forward for at least 100 meters or to the maximum effective range of the weapon if time permits.

remove the lower branches of large scattered trees in sparsely wooded areas.

(2) Restrict work to thinning the undergrowth and removing the lower branches of large trees when clearing in heavy woods. Clear narrow lanes of fire for automatic weapons.

(3) Thin or remove dense brush since it is never a suitable obstacle and obstructs the field of fire.

(4) Cut weeds when they obstruct the view from firing positions.

(5) Remove felled limbs, brush, and weeds to areas where they cannot be used to conceal enemy movements or disclose your position.

(6) Do only a limited amount of clearing at one time. Overcommitting the unit may result in a field of fire improperly cleared. This would benefit the enemy.

(7) Cut or burn grain, hay, and tall weeds.

*c. Man-hours Required.*

(1) Approximately 5 man-hours per hundred square meters are required to clear average growth.

(2) Add 50 percent if working in darkness.

## Section II. TYPES OF FORTIFICATIONS

### 4-3. EMPLACEMENTS

*a. Requirements.* Emplacements should be constructed to:

- (1) Permit each individual to accomplish assigned fire missions.
- (2) Be simply and easily constructed.
- (3) Provide maximum protection with minimum time and labor.
- (4) Be camouflaged and concealed.
- (5) Provide protection against mechanized attack.
- (6) Provide protection against nuclear attack.

*b. Types and Dimensions - Frontal Parapet Fighting Positions (figures 4-1 through 4-7).*

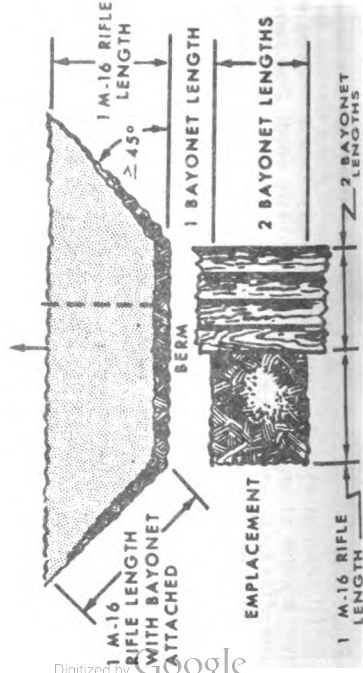


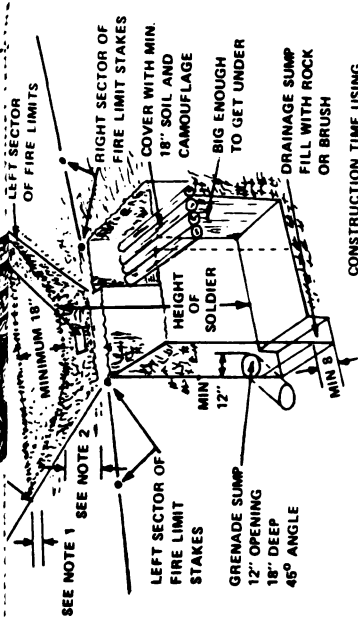


FEET ARE PLACED MORE THAN SHOULDER WIDTH APART

Figure 4-1. Measurements, one-man emplacement.

#### DIRECTION OF ATTACK





CONSTRUCTION TIME USING  
ENTRENCHING TOOLS - 8 HOURS

#### NOTES:

1. END OF PARAPET MUST BE AT LEAST 4" HIGHER THAN MUZZLE OF WEAPON WHEN IN FIRING POSITION.
2. REAR OF PARAPET MUST BE HIGH ENOUGH TO PROTECT A MAN'S HEAD.

Figure 4-3. One-man emplacement (cross-sectional view).

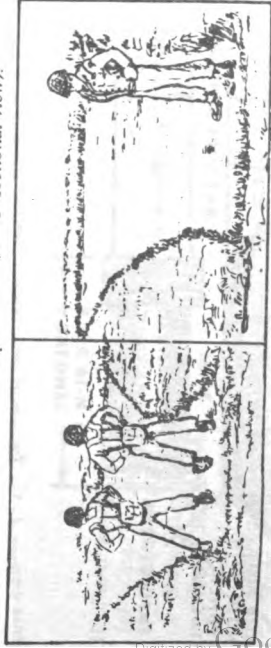


Figure 4-4. Measurements, two-man emplacement.

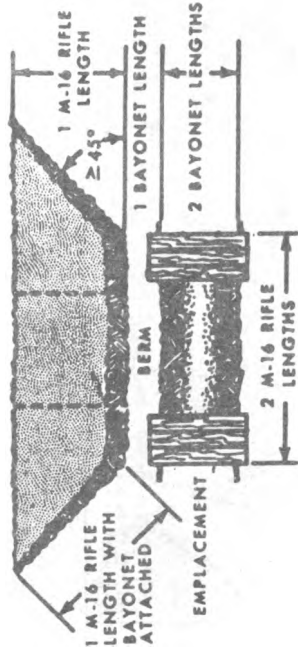
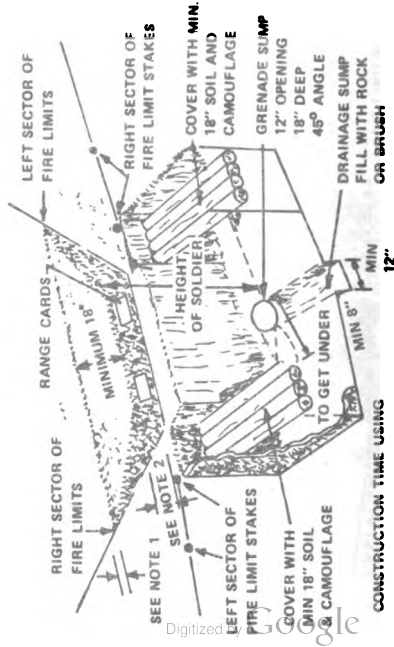


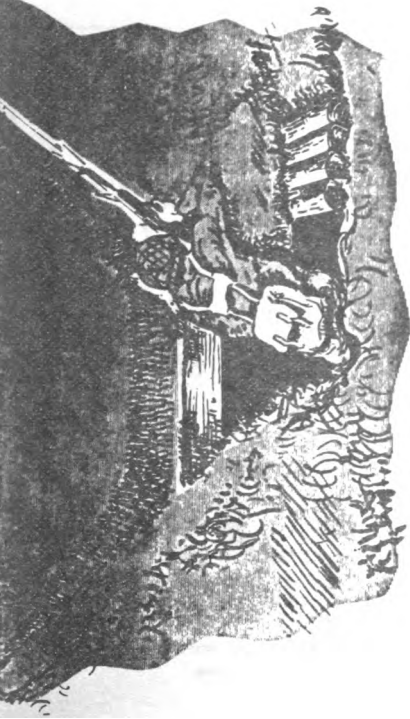
Figure 4-5. Two-man emplacement (vertical view).



CONSTRUCTION TIME USING  
ENTRENCHING TOOLS - 8 HOURS

NOTES:

1. END OF PARAPET MUST BE AT LEAST 4" HIGHER THAN MUZZLE OF WEAPON WHEN IN FIRING POSITION.



*Figure 4-7. Occupied one-man emplacement.*

c. *Foxhole Digger Explosive Kit.* This item greatly increases a unit's capability to create emplacements with a minimum of time and labor. See figure 4-8.

(1) *Characteristics.*

(a) *Case.*

Material—Plastic

Shape—Tubular

Size—7.38 x 2.28 in.

(b) *Shaped charge.*

Material—Plastic and copper

Shape—Tubular

Size—7.37 x 2.0

*(c) Cratering charge.*

Material—Pressed explosive inside sleeve

Shape—Tubular

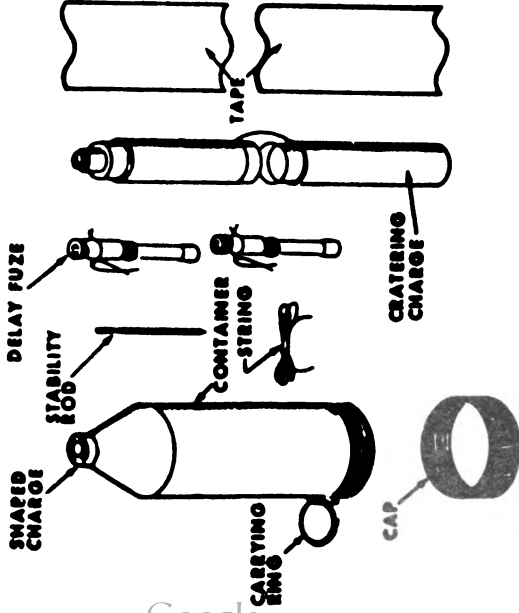
Size—8.21 x 1.0 in.

*(d) Fuze.*

Material—Steel

Shape—Tubular

Size—4.25 x 0.56 in.

*(e) Basis of issue. Individual combat soldier*

- (1) REMOVE ALL PARTS FROM INSIDE CONTAINER
- (2) LEAVE CAP OFF

Type of emplacement or shelter	Total construction time in man hours for construction with D-handle shovels and ordinary carpentry tools				
	Revetment materials for cover support only		Complete revetment		No revetment materials used
	Corrugated metal constr.	Sized lumber constr.	Corrugated metal constr.	Sized lumber constr.	
Improved crater .....	N/A	N/A	N/A	N/A	0.5
Skirmishers trench .....	N/A	N/A	N/A	N/A	0.5
Prone emplacement .....	N/A	N/A	N/A	N/A	1.5
Open one man foxhole .....	N/A	N/A	3.5	4.5	2.0
Open one man foxhole with offset .....	9.0	14.0	10.0	16.0	N/A
One man foxhole with half cover .....	2.5	3.0	4.5	5.5	N/A
One man foxhole with half cover and offset .....	10.0	14.0	12.0	18.0	N/A
Open two man foxhole .....	N/A	N/A	6.0	8.0	3.0
Deepened two man foxhole .....	N/A	N/A	8.0	10.0	5.0
Two man foxhole with half cover .....	4.0	4.0	8.0	10.0	N/A
Two man foxhole with half cover and two offsets .....	20.0	30.0	22.0	35.0	N/A
Two man foxhole with half cover and adjoining shelter .....	11.0	17.0	13.0	22.0	N/A
Open fighting trench (25' length) .....	N/A	N/A	28.0	32.0	21.0
Fighting trench with full cover (25' length) .....	27.0	29.0	35.0	40.0	N/A

Figure 4-9. Time required to construct individual, crew-served, and artillery weapons emplacements.

Type of emplacement or shelter	Total construction time in man hours for construction with D-handle shovels and ordinary carpentry tools				
	Revetment materials for cover support only		Complete revetment		No revetment materials used
	Corrugated metal constr.	Sized lumber constr.	Corrugated metal constr.	Sized lumber constr.	
Open automatic rifle emplacement . . . . .	N/A	N/A	7.0	8.0	4.0
Automatic rifle emplacement with 18" of cover . . . . .	4.0	5.0	6.0	7.0	N/A
Open horseshoe type M60 machinegun emplacement . . . . .	N/A	N/A	8.0	10.0	4.0
Open 2 one-man foxhole type light machinegun emplacement. . . . .	N/A	N/A	6.0	7.0	4.0
Horseshoe type light machinegun emplacement with full cover. . . . .	9.0	11.0	11.0	14.0	N/A
2 one-man foxhole lt. machinegun type emplacement with 1/2 cover and adjoining shelter . . . . .	15.0	22.0	19.0	28.0	N/A
Circular type .50 cal machinegun emplacement . . . . .	N/A	N/A	14.5	16.5	10.0
Pit type emplacement for recoilless weapons . . . . .	N/A	N/A	5.0	6.0	3.0
81-mm mortar emplacement . . . . .	N/A	N/A	12.0	N/A	N/A
4.2-inch mortar emplacement . . . . .	N/A	N/A	29.0	N/A	N/A
Recoilless rifle position (mounted) . . . . .	N/A	N/A	N/A	N/A	30.0
Recoilless rifle position (dismounted) . . . . .	N/A	N/A	N/A	N/A	17.0
105-mm howitzer emplacement . . . . .	N/A	N/A	N/A	N/A	100.0
155-mm howitzer emplacement . . . . .	N/A	N/A	N/A	N/A	170.0

Figure 4-9. Time required to construct individual, crew-served, and artillery weapons emplacements (Con't).

(a) The shaped charge will penetrate soil, depending on the density, to depths varying from 50 to 85 cm. (19.7 to 33.5 in.), forming a tapered hole 6 cm. (2.4 in.) in diameter at the top and 1.5 cm. (0.6 in.) at the bottom.

(b) The cratering charge will form a crater in soil about 107 cm (42 in.) in diameter and about 80 cm (31.5 in.) deep.

#### 4-4. REVETMENTS

a. *Retaining Wall Type.* Used in relatively unstable soils. The horizontal layers of the walls are tied together so that the wall acts as a structural unit. Revetments may be constructed of sandbags, sod blocks, and other expedients. The methods of construction are as follows:

(1) *Sandbags (fig. 4-10).*

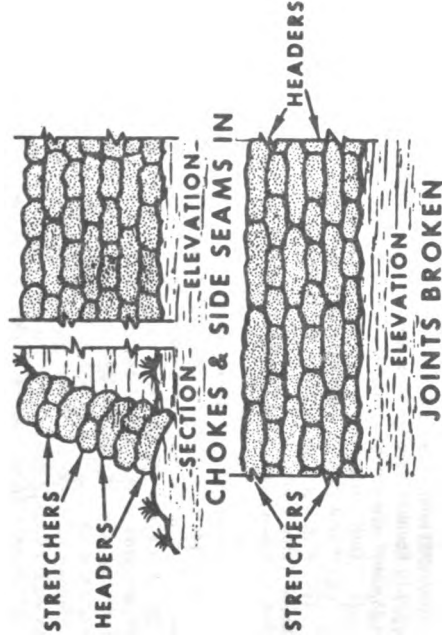


Figure 4-10. Sandbag retaining wall.



- (a) Fill three-fourths full.
- (b) Stabilize bags by filling with 1 part cement to 10 parts dry earth. In a sand-gravel mixture, increase ratio to 1 to 6.
- (c) Tuck in bottom corner of bags after filling.
- (d) Place all bags on bottom row as headers (fig. 4-10).
- (e) With stabilized sandbags, the foundation should be about 15 centimeters below floor level.
- (f) Alternate intermediate rows as headers and stretchers.
- (g) Slope the wall toward revetted face at slope of 1 to 4.
- (h) Place bags perpendicular to slope.
- (i) Place about 800 sandbags per 25 square meters of revetted surface.

(2) *Sod blocks (thick sod with good roots).* Cut sod blocks into 20 by 45 centimeter sections and lay flat, using alternate stretcher-method as with sandbags. Lay sod grass-to-grass and soil-to-soil except for the top layer which is placed with grass upward for camouflage. Drive two wooden pegs through each section of every layer as it is completed. Lay sod revetment at a slope of 1 to 3.

(3) Expedients, such as ice blocks, may be used in cold weather. Stack them in the same way as sandbags or sod, and run water over them in order to bind them by freezing. Another expedient is earth-filled packing cases or ammunition boxes which are placed in position and nailed to the layer below. The boxes are then filled with earth or rock. In wooded areas small timber may be used as revetting material.

b. *Facing Type.* Serves mainly to protect surfaces from weather and damage caused by occupation. It consists of facing material, the top of which is set below ground level so that the revetting material is not damaged by tanks crossing the emplacement.

(1) *Types of material.* Materials used in facing may be brushwood hurdles, continuous brush, pole and dimensional timbers, corrugated metal, or burlap and chicken wire. Construction methods are described in paragraph 4-4-b-(3) below.

(2) *Methods of support.*

(a) Timber frames of dimensioned timber are built to fit the bottom and sides of the position and hold the facing material apart. This insures that the excavated width remains stable.

**PLATE 2**



**Figure 4-11. Method of anchoring retaining wall posts/pickets.**

### (3) *Methods of constructing facing type revetments*

(a) The size of pickets depends upon the soil type and the kind of facing material, but timber pickets should not be smaller than 8.0 centimeters in diameter. Maximum spacing between pickets should be 1.75 meters. U-shaped pickets are excellent for revetting. Pickets are driven at least 0.5 meters into the floor of the position. Where the pickets are anchored at the top, proceed as shown in figure 4-11.

- (b) A brushwood hurdle is a woven revetment unit, usually 1.75 to 2.0 meters long and of required height.
- (c) The pole revetment is similar to the continuous brush revetment, except that a layer of small horizontal round poles cut to wall length is used. If available, boards or planks are used.
- (d) Corrugated metal sheets or pierced steel planks are strong, durable, and rapidly installed. They may be used for any height or length of revetment. Smear metal surfaces with mud to eliminate possible reflection of thermal radiation and to aid camouflage.

#### 4-5. BUNKERS

- a. In bunker design two basic criteria must be considered:
  - (1) The purpose of the bunker (CP, firing positions, etc.).
  - (2) Weapons from which protection is desired (small arms, mortars, bombs, etc.).
- b. A bunker should be constructed wholly or partly below ground level. If above ground level, columns or posts should extend below ground level for anchoring.
- c. The protective cover and roof of a bunker should be designed so that it moves freely but is rigid enough to displace as a unit. It must also be able to absorb the shock of an exploding shell. To accomplish this, sandwich type construction is used. See figures 4-12 and 4-13. The burster course and roof structure must be both rigid and resilient and the middle layer be porous and capable of cushioning against shock.
- d. In timber construction, notching of lumber should be avoided.
- e. All bunkers should have overhead cover of at least 18 inches in order to defeat an 81-mm mortar surface burst.

#### 4-6. SHELTERS

The most effective shelters are underground cut and cover. Typical shelters, shown in figures 4-14 through 4-16, are constructed in accordance with the following instructions:

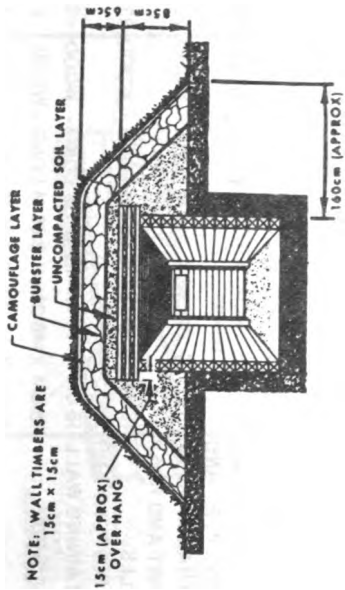


Figure 4-12a. Bunker (interior view).

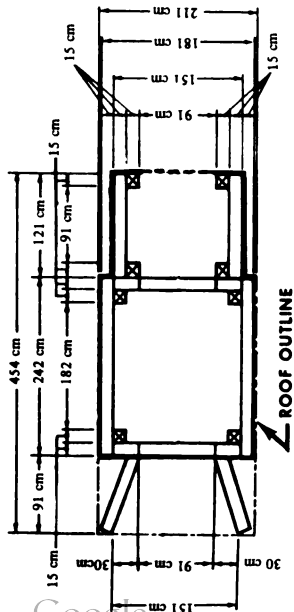


Figure 4-12b. Bunker (plan view).

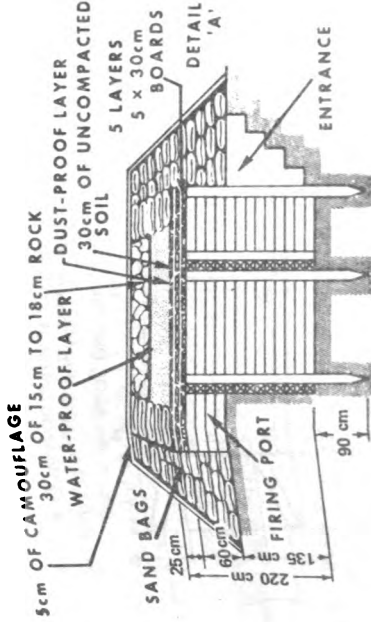


Figure 4-12c. Bunker

ITEM	DESCRIPTION	NO. PCS
ROOF	5 CM X 30 CM X 2.11 M LONG	48 PCS
	5 CM X 30 CM X 4.54 M LONG - WOOD	14 PCS
SIDE WALLS	15 CM X 15 CM X 2.42 M LONG - WOOD	26 PCS
ENTRANCE WALL	15 CM X 15 CM X 1.21 M LONG - WOOD	26 PCS
FIRING PORT AND ENTRANCE DOOR	15 CM X 15 CM X 30 CM LONG - WOOD	26 PCS
FRONT AND REAR WALLS	15 CM X 15 CM X 1.51 M LONG - WOOD	13 PCS
FIRING PORT AND RETAINING WALL	15 CM X 15 CM X 1.00 M LONG - WOOD	8 PCS
SIDE POST	15 CM X 15 CM X 2.85 M LONG - WOOD	6 PCS
SIDE POST	15 CM X 15 CM X 1.95 M LONG - WOOD	2 PCS

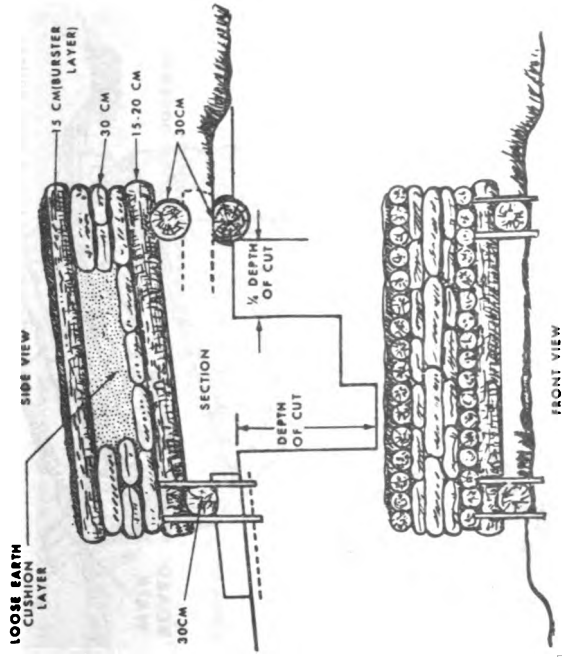
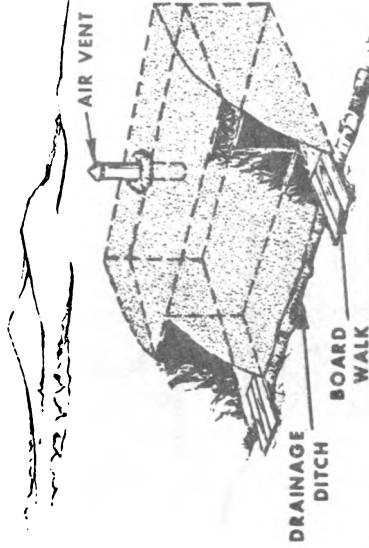
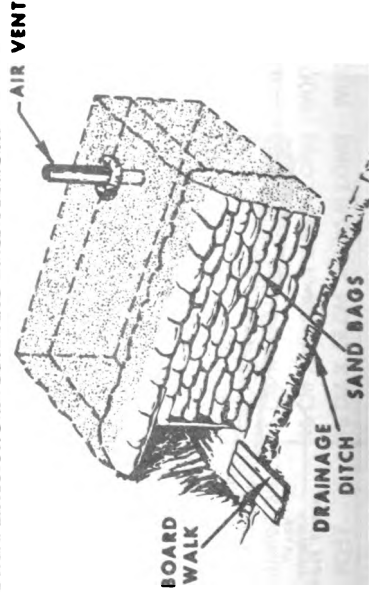


Figure 4-13. Fighting bunker with overhead cover.



CUT-AND-COVER SHELTER IN A HILLSIDE (BAFFLE WALL OF ENTRANCE CAMOUFLAGE OMITTED) SHADED AREA AND BROKEN LINES SHOW CUT-AND-FILL SECTION.



CUT-AND-COVER SHELTER IN ACUT BANK SHOWING SAND-BAGGED ENTRANCE (CAMOUFLAGE OMITTED) SHADED AREA AND BROKEN LINES SHOW CUT-AND-FILL SECTION.



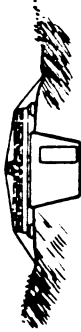
1. EXCAVATE WITH EXPLOSIVES



2. SHAPE EXCAVATION & ERECT BUNKER



3. BACKFILL



4. CONSTRUCT ROOF, DIG DOORWAY  
AND DRAINAGE DITCHES

Figure 4-15. Air transportable underground assault bunker (prefab).

### BILL OF MATERIALS

4' x 8' x 3/4" PLYWOOD	20 EA
4" x 8" x 14' TIMBERS	13 EA
4" x 4" x 8' TIMBERS	10 EA
4" x 4" x 10' TIMBERS	2 EA
2" x 4" x 12' TIMBERS	4 EA
2" x 4" x 10' TIMBERS	9 EA
2" x 4" x 8' TIMBERS	10 EA
TRIM (METAL EDGING)	190 FT

### OPTIONAL

BOLTS (FOR HINGES)	128 EA
WOOD SCREWS (OR # 8 NAILS)	5 LB
PAINT (O. BRAB)	1 GAL
HINGES	16 EA
U-BOLTS W/BEARING PLATES	4 EA

Figure 4-16. Bill of materials (air transportable underground bunker).



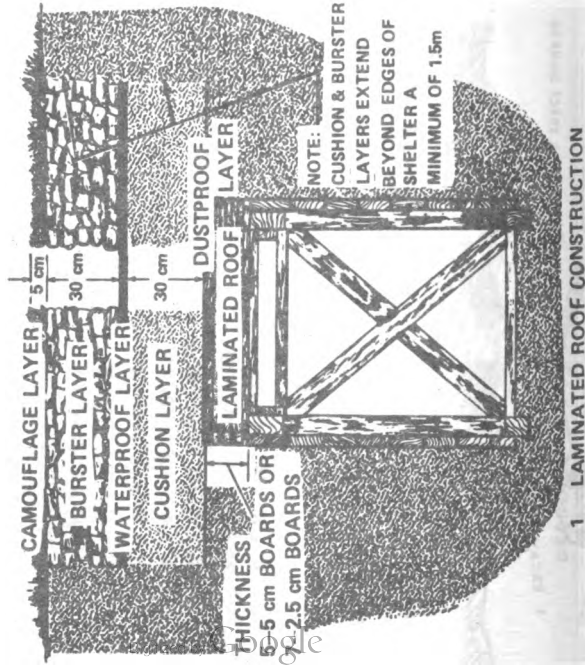
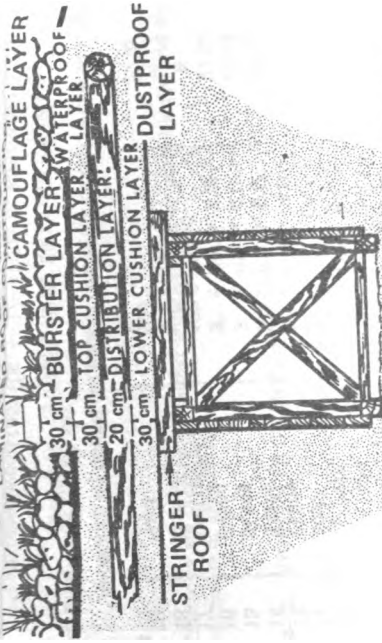


Figure 4-17a. Heavy overhead cover (laminated roof construction).



NOTE: THE CONSTRUCTION IS SIMILAR TO LAMINATED ROOF CONSTRUCTION WITH THE ADDITION OF—

- (1) A LOWER CUSHION LAYER 30 cm THICK ON TOP OF THE DUSTPROOF LAYER. THIS LAYER OF UNTAMPEDED EARTH DOES NOT EXTEND BEYOND THE SIDES OF THE SHELTER.
- (2) A DISTRIBUTION LAYER CONSISTING 20 cm TIMBERS. THIS LAYER EXTENDS BEYOND EACH SIDE OF THE SHELTER A MINIMUM OF 1.5 METERS AND RESTS ON UNDISTURBED EARTH TO TRANSMIT PART OF THE LOAD OF THE TOP LAYERS TO THE UNDISTURBED EARTH ON EACH SIDE OF THE SHELTER.

Figure 4-17b. Heavy overhead cover (stringer roof construction).

Table 4-1. Bill of Materials for One 6' x 8' Sectional Shelter With Post, Cap and Stringer Construction—Dimensional Lumber

Material List			
No.	Nomenclature	Rough size	Quantities
1	Cap or sill	6" x 8" x 8'0"	4
2	Post	6" x 6" x 5'10"	6
3	Stringer**	6" x 6" x 6'0"	16
4	Spreader	3" x 6" x 5'0"	4
5	Post, door	3" x 6" x 6'6"	1
6	Brace	*3" x 6" x 7'0"	1
7	Brace	*3" x 6" x 6'10"	3
8	Brace	*3" x 6" x 8'0"	2
9	Spreader	2" x 6" x 3'3"	3
10	Spreader	2" x 6" x 2'9"	2
11	Spreader	2" x 6" x 2'0"	2
12	Scab	3" x 6" x 2'0"	2
13	Siding	3" x RW x 8'0"	41 1/3 SF
14	Siding	3" x RW x 6'0"	36 SF
15	Siding	3" x RW x 4'0"	24 SF
16	Siding	3" x RW x 3'6"	21 SF
17	Roll roofing	100 Sq ft roll	6
18	Driftpin	1/2" x 14"	44
19	Nails	60d	32 lb

\* Allowance for double cut ends of braces is included in overall length as shown under rough size.

\*\* Laminated wood cut ends (Fig. 4-17) may be substituted if desired

#### 4-7. TYPES

Obstacles are classified as either antipersonnel or antivehicular and may be deliberate or expedient.

#### 4-8. PRINCIPLES OF EMPLOYMENT

In order to be effective, obstacles should be:

- a.* Under friendly observation, covered by fire, and protected by antipersonnel mines, flame mines, and warning devices.
- b.* Concealed from enemy observation by incorporating terrain features such as reverse slopes, hedges, woods, and fence lines.
- c.* Erected in irregular traces.
- d.* Employed in depth.
- e.* Coordinated with other elements of the defense.
- f.* Tied in with other obstacles.
- g.* Provided with lanes and gaps.
- h.* Of no advantage to the enemy.

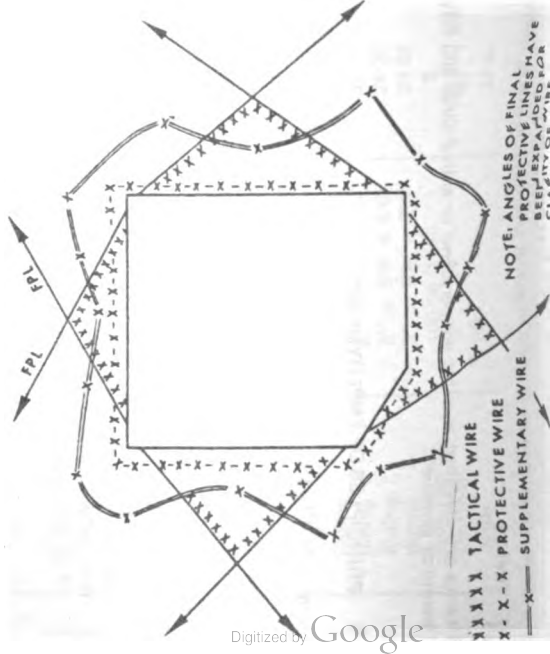
#### 4-9. CLASSIFICATION OF BARBED WIRE

- a. Belt.* One entanglement, one fence in depth.
- b. Band.* Two or more belts with no interval between them. The band may be composed of two or more fences of different types, in which case it would be called a combination band.
- c. Zone.* Two or more bands or belts in depth with intervals between them.

#### 4-10. ESTIMATING BARBED WIRE REQUIREMENTS

a. *Conventional Deployment.* (along FEBA) Rules of Thumb.

- (1) Tactical wire; (front)  $\times (1.25) \times$  (number of belts).
  - (2) Protective wire; (front)  $\times (5) \times$  (number of belts).
  - (3) Supplementary wire.
    - (a) Forward of FEBA, (front)  $\times (1.25) \times$  (number of belts).
    - (b) Rear of FEBA;  $(2.5) \times$  (unit depth)  $\times$  (number of belts).
- b. *Base Camp Defense (fig. 4-18).* (along perimeter) Rules of Thumb.

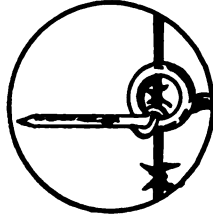


- (1) Tactical wire, (mean perimeter)  $\times$  (1.25)  $\times$  (number of belts).
- (2) Protective wire; (perimeter)  $\times$  (1.10)  $\times$  (number of belts).
- (3) Supplementary wire; (mean perimeter)  $\times$  (1.25)  $\times$  (number of belts).

c. *Supply and Labor.* For construction estimates of man-hours and materials, see tables 4-2 and 4-3.

#### 4-11. BARBED WIRE TIES

Various barbed wire ties are shown in figure 4-19.



**TOP-EYE TIE**



**INTERMEDIATE-EYE  
TIE**



**APRON TIE**



**POST TIE**

*Figure 4-19. Barbed wire ties.*

Table 4--2. Wire and Tape Entanglement Materials

Materials	Approx weight, kg	Approx length, m	No. carried by one man	Approx weight of man-load kg
Barbed wire reel	41.5	400	$\frac{1}{2}$	21
Bobbin	3.5--4.0	30	4--6	14.5--24.5
Barbed tape dispenser	0.77	0.45	20	15.5
Barbed tape carrying case	14.5	300	1	14.5
Standard barbed tape concertina	14	15.2	1	14
Standard barbed wire concertina	25.4	15.2	1	25
Expedient barbed wire concertina	13.5	6.1	1	13.5
General purpose barbed tape obstacle				
Hand	16	20	2	32
Vehicular	112	140	1	112
Screw pickets:				
Long	4	1.6	4	16.3
Medium	2.7	0.81	6	16.3
Short	1.8	0.53	8	14.5
U-shaped pickets:				
Extra long	7.25	2.4	3--4	21.8--19.0
Long	4.5	1.5	4	18.1
Medium	2.7	0.81	6	16.3
Short	1.8	0.61	8	14.5
Wooden pickets:				
Extra long	7.7--10.5	2.13	2	15.4--20.8
Long	5.4--7.25	1.5	3	16.3 21.7
Short	1.3--2.4	0.76	4	11.3 21.7

Table 4--3. Material and Labor Requirements for 300-Meter Sections of Various Barbed Wire Entanglements

Type of entanglement	Pickets			Reels of barbed wire (a)	No. of GPBTO (f)	No. of concertinas	Staples	Man- hours to erect (c)	Kgs of materials per lin m of entanglement (b)
	Long	Med	Short						
Double-apron, 4- and 2-pace	100		200	14-15 <sup>d</sup> (19)				59	4.6 <sup>e</sup> (3.5)
Double-apron, 6- and 3-pace	66		132	13-15 <sup>d</sup> (18)				49	3.6 <sup>e</sup> (2.6)
High wire (less guy wires)	198			17-19 <sup>d</sup> (24)				79	5.3 <sup>e</sup> (4.0)
Low wire, 4- and 2-pace		100	200	11				49	3.6 <sup>e</sup> (2.8)
4-strand fence	100		2	5-6 <sup>d</sup> (7)				20	2.2 <sup>e</sup> (1.8)
Triple standard concertina	160		4	3 <sup>d</sup> (4)		59	317	30	8.2 <sup>e</sup> (7.3)
General purpose barbed tape obstacle (GPBTO)					<sup>f</sup> (8)			<sup>f</sup> (1)	2.7

a. Lower number of reels applies when screw pickets are used; higher number when U-shaped pickets are used. Add difference between the two to the higher number when wood pickets are used.

b. Average weight when any issue metal pickets are used (1 truckload = 2268 kgs).

c. Man-hours are based on the use of screw pickets. Multiply these figures by .67 if experienced troops are being used, and by 1.5 for night work. With the exception of triple standard concertina and GPBTO, multiply these figures by 1.2 when using any type driven picket.

d. Number of barbed tape carrying cases required if barbed tape is used in place of barbed wire.

e. Kgs of materials required per linear meter of entanglement if barbed tape is used in place of barbed wire and barbed tape concertina is used in place of standard barbed wire concertina.

f. Based on vehicular emplaced obstacles installed in triple belts.



## 4-12. BARBED STEEL TAPE

Barbed steel tape (fig. 4-20) and barbed tape concertina can be used in the same manner as standard barbed wire and concertina for the construction of barbed wire entanglements. Wrap around ties are used with barbed steel tape similar to the post tie used with barbed wire (fig. 4-19). However, barbed tape must not be pulled tight as it will break when bent sharply. A special dispenser is used to impart a twist to the tape when constructing fences. Recovery of the barbed steel tape for reuse in a standard fence is usually not practical. However, it should be recovered and used to increase the density of other existing entanglements.

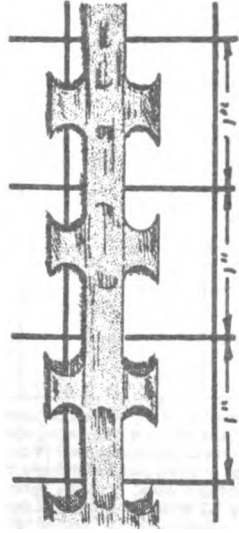


Figure 4-20. Barbed steel tape.

## 4-13. DOUBLE-APRON FENCE, FOUR- AND TWO-PACE

- a. Erect from right to left as you face the enemy (fig. 4-21).
- b. Space pickets as follows:
  - (1) Long pickets are 4 paces apart.
  - (2) Anchor pickets are placed 2 paces from the centerline at midpoint between center pickets and at each end of fence 4 paces from the first and

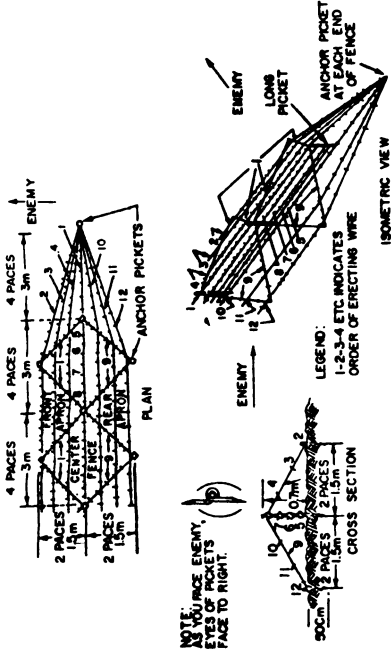


Figure 4-21. Double-apron fence.

#### 4-14. DOUBLE-APRON FENCE, SIX-AND THREE-PACE

Erection is the same as in paragraph 4-13 using 6 paces instead of 4 and 3 paces instead of 2.

#### 4-15. CONSTRUCTION PROCEDURE FOR DOUBLE APRON FENCES

a. *First Operation—Layout and Installation of Pickets (3 Crews).*

- (1) First crew lays out long pickets.
- (2) Second crew lays out short pickets.
- (3) Third crew installs all pickets.

b. *Second Operation—Layout and Installation of Wire.* Men are organized into two crews of four men each.

- (1) First wire, enemy diagonal.
- (2) Second wire, enemy tripwire (5-10cm off the ground).
- (3) Third and fourth wire, enemy apron.

- (4) Fifth, sixth, seventh, eighth, center fence (install from the bottom up).
- (5) Ninth wire, friendly diagonal.
- (6) Tenth and eleventh wire, friendly apron.
- (7) Twelfth wire, friendly tripwire.

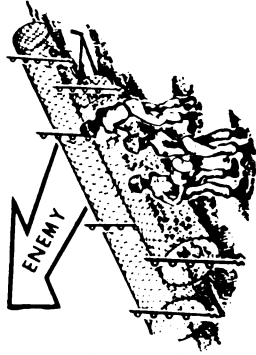
#### 4-16. TRIPLE STANDARD CONCERTINA

- a. Erect from right to left as you face the enemy (fig. 4-22).
- b. Space pickets as follows:
  - (1) Long pickets are 5 paces apart.
  - (2) Anchor pickets are placed 2 paces from the end of long pickets.
  - (3) Enemy and friendly rows of pickets are 3 feet (0.9m) apart.
  - (4) Friendly picket row is offset from the enemy row.
- c. Concertina fences are constructed of barbed wire concertina, barbed tape concertina, or general purpose barbed tape obstacle. There is no difference in construction methods for the first two types. Construction methods for the tape obstacle are given in paragraph 4-18.



STEP 1

INSTALL FRONT ROW  
AND HORIZONTAL WIRE



STEP 2

INSTALL TOP ROW  
AND RACK TO WIRE



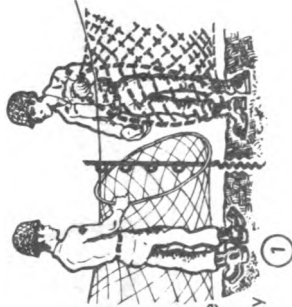
INSTALL TOP ROW  
AND RACK TO REAR  
HORIZONTAL WIRE

#### 4-17. CONSTRUCTION PROCEDURE - TRIPLE STANDARD CONCERTINA

##### a. First Operation (3 Crews).

- (1) First crew lays out all pickets.
- (2) Second crew installs all pickets.
- (3) Third crew lays out concertinas.

- (a) Lay one concertina in front of third picket on enemy side.
- (b) Lay two concertinas to rear of third picket on friendly side.
- (c) Remove binding wire and place on handles.
- (d) Repeat same performance every fourth picket thereafter.

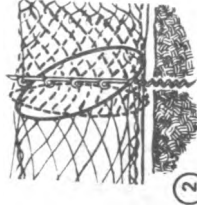


##### b. Second Operation (All Personnel).

- (1) Install front row concertina and horizontal wire.

- (a) Drop concertinas over pickets.
- (b) Join concertina (fig. 4-23).

PLACE BOTTOM PORTION  
OF FIRST COIL OVER  
PICKET



PLACE BOTH BOTTOM  
AND TOP PORTION  
OF SECOND COIL  
OVER PICKET



PLACE TOP PORTION OF  
FIRST COIL OVER PICKET

Figure 4-23. Joining concertinas.

- (2) Install rear row concertina and horizontal wire.
- (3) Install top row concertina and rack to the rear horizontal wire.

#### 4-18. GENERAL PURPOSE BARBED TAPE OBSTACLE (GPBTO)

a. *Description.* The GPBTO consists of two concentric helical coils of steel spring tape which are 30 and 24 inches in diameter, respectively (fig. 4-24). The GPBTO is available in a seven-module package containing sufficient tape to erect an obstacle 140 meters long. The obstacle may be erected by vehicle, or individual sections may be detached and manually replaced by vehicle, and anchor stakes are included in each container. Recovery tools and anchor stakes are included in depth.

GPBTO should be employed as a band, 3 belts in depth.



path until all the tape is dispensed. Hand emplacement requires one-twentieth the time and vehicular emplacement one-fiftieth the time required to erect concertina. Further instructions are included with each container.

c. *Safety.* Gloves should *NOT* be worn when handling the GPBTO. While gloves will reduce minor scratches, they tend to give a false sense of security. The GPBTO barbs are so sharp that they easily penetrate gloves without sufficient resistance to give a warning. Consequently, the hand can be punctured easily when the glove is worn and it can be very difficult to extract the barb from the hand if other barbs are tangled in the glove.

#### 4-19. LOW WIRE FENCE

This is like a 4 and 2 pace double-apron fence, except that medium pickets instead of long pickets are used in the centerline. This results in all apron and diagonal wires being much closer to the ground. The numbers 5, 6, and 7 wires are not used. This obstacle is easily hidden in tall grass or shallow water. For best results, it should be used in depth.

#### 4-20. FOUR-STRAND CATTLE FENCE

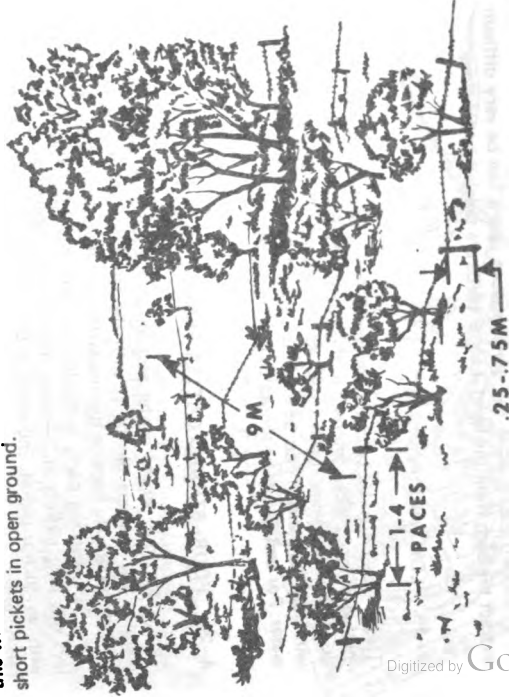
This is the four-strand center section of a double-apron fence. In farm country this obstacle blends in with the landscape. If guy wires are used, estimate separately because this material is not included in table 4-3.

a. The working party is divided into two equal groups. The first group lays out long pickets at 3-meter intervals. It begins and ends the section with an anchor picket, including anchor pickets for guys, if needed. The second group installs the pickets.

b. Teams of two or four men are then organized to install wires. The four-man teams, two men carry the reel, and two make ties and tighten the wire. In two-man teams, the wire is unrolled for 5- to 100 meters before ties are made. The wires are installed from the bottom up.

## 4-21. TANGLEFOOT

Tanglefoot is used where concealment is needed (fig. 4-25). Use it in a minimum depth of 9 meters. Place pickets at irregular intervals of from 0.75 to 3 meters. Height of the barbed wire varies from 0.25 to 0.75 meters. Site this wire in scrub if possible. Use bushes as supports for part of the wire. Use short pickets in open ground.



NOTE: TANGLEFOOT, AS PICTURED, IS DESIGNED TO DISRUPT ENEMY DURING AN ASSAULT. WHEN USED AS A COUNTER-SAPPER MEASURE THE TANGLEFOOT SHOULD BE STRUNG OUT AT IRREGULAR CRISS-CROSS PATTERNS SO AS TO CREATE RECTANGLES OR SQUARES OF ABOUT .6 x .6 METERS AT VARYING HEIGHTS OF 10-15 CENTIMETERS. DOING THE ABOVE SHOULD CAUSE THE SAPPER TO HAVE TO RISE OVER THE WIRE EXPOSING HIM TO FIRE.

Figure 4 25. Tanglefoot.

## PORTABLE BARBED WIRE OBSTACLES

- a. Standard concertinas are considered portable as they are readily moved.
- b. The knife rest (fig. 4-26) is a portable wooden or metal frame strung with barbed wire. It is about 4.5 meters long and 1.2 meters high. It must be securely fixed in position.

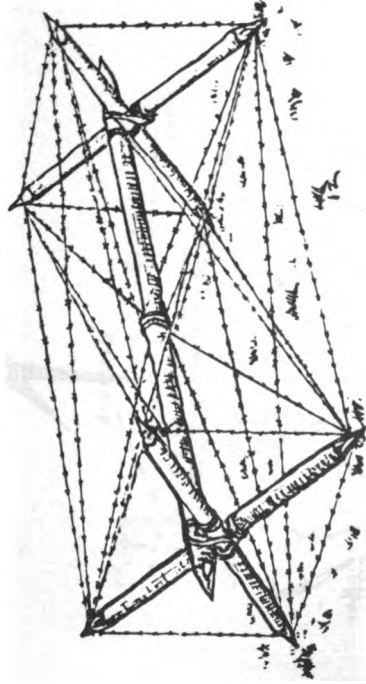


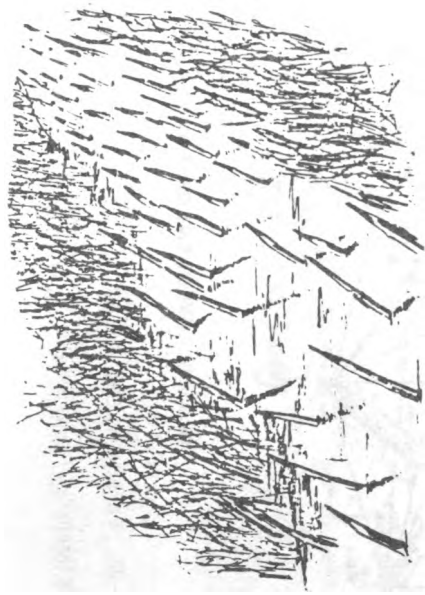
Figure 4-26. Knife rest.

## Section IV. EXPEDIENT OBSTACLES

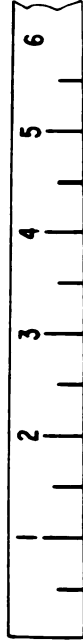
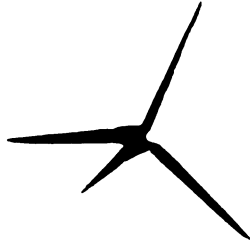
### 4-23. EXPEDIENT OBSTACLES

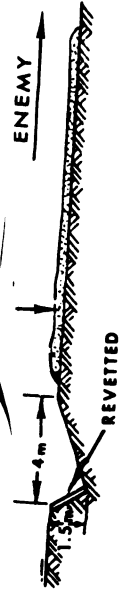
See figures 4-27 through 4-34



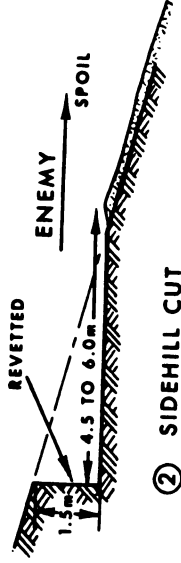


*Figure 4-27. Belt of imbedded sharpened stakes.*

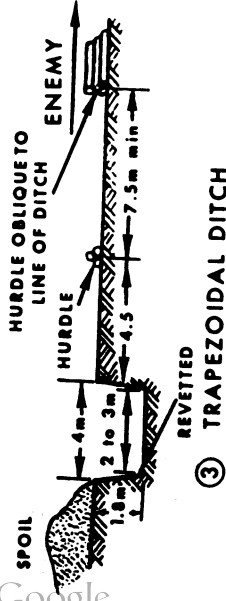




① TRIANGULAR DITCH

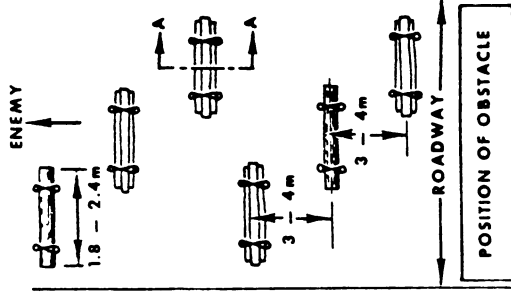


② SIDEHILL CUT

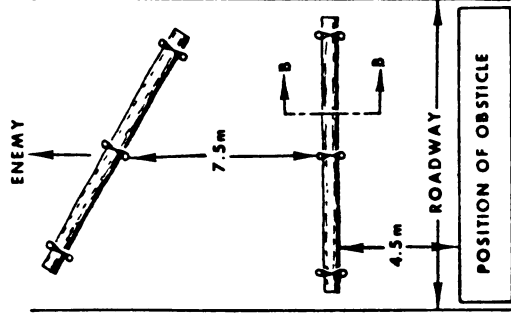


③ TRAPEZOIDAL DITCH

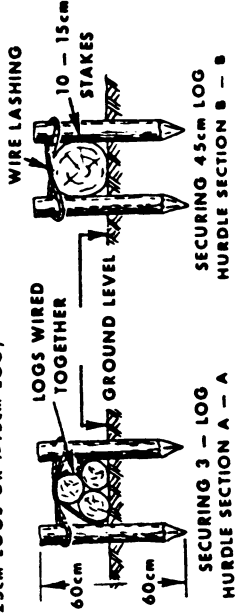
Figure 4-29. Trapezoidal ditch.



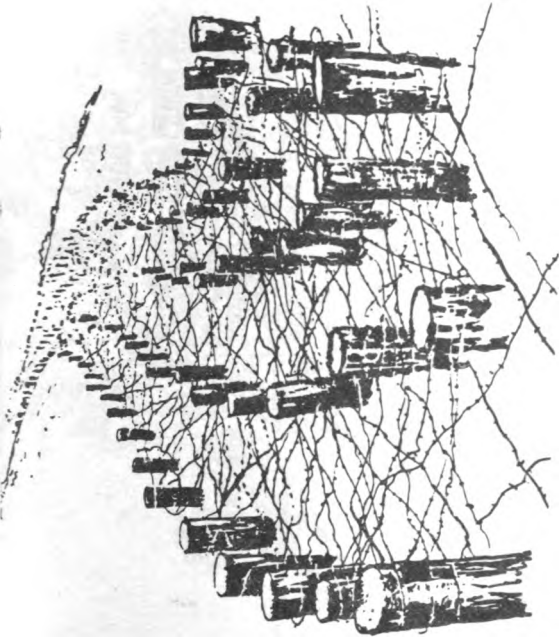
EMPLOYMENT OF STAGGERED  
1.8 - 2.4 m HURDLES  
(3-25cm LOGS OR 1-45cm LOG)



EMPLOYMENT OF 45cm  
LOGS AS HURDLES



Employ a minimum of three hurdles per site



**MIN DEPTH: 4 ROWS**

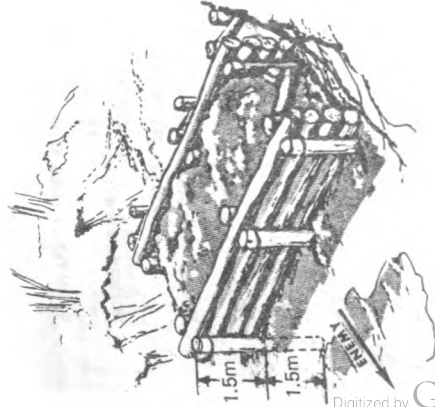
**SPACING: IRREGULAR, 1 TO 2m BETWEEN POSTS (AVG 1.5m)**

**HEIGHT: IRREGULAR 78cm TO 120 cm ABOVE GROUND  
AND 150 cm BELOW GROUND.**

**NUMBER OF POSTS =  $\frac{(\text{FRONT}) 4}{1.5}$**

**DIAMETER OF LOGS, 40 cm**

*Figure 4-31. Post obstacles.*



Number of posts

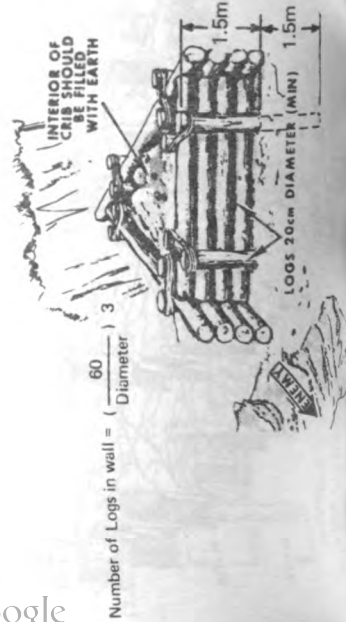
$$\text{Long} = \left( \frac{WR}{6} + 1 \right) 4$$

$$\text{Short} = \frac{WR}{6} + 1$$

$$\text{Diagonal} = \left( \frac{WR}{6} + 1 \right) 2$$

Number of Logs

$$\text{Logs} = \left( \frac{60}{\text{Diameter}} \right) 2 + 1$$



$$\text{Number of Logs in wall} = \left( \frac{60}{\text{Diameter}} \right) 3$$



Figure 4-33. Abatis used as a roadblock.

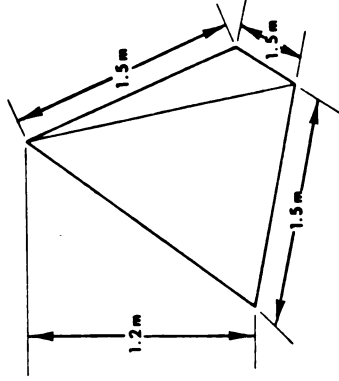
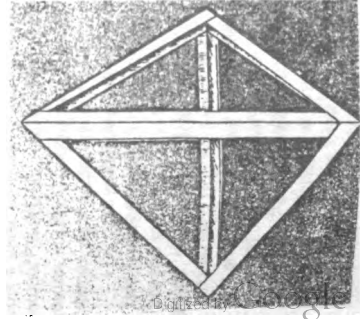


Figure 4-34. Tetrahedrons.

## CHAPTER 5

## MARKING OF BRIDGES AND VEHICLES

## Section I. BRIDGES

## 5-1. MARKING OF BRIDGES

*a. Classification.*

(1) The class number of a bridge represents the safe load—carrying capacity of a single-lane bridge or a single lane of a multilane bridge under normal crossing conditions. The bridge class number may be a *single class* number, which will permit either wheeled or tracked vehicles to cross if the vehicle class number is equal to or less than the bridge class number, or it may be a *dual class* number, which indicates one normal class number for wheeled vehicles and another normal class number for tracked vehicles. Dual classification may be used for bridges with a capacity greater than class 30. For reconnaissance reports and tables, dual class numbers are written with the wheeled class number in parentheses above the tracked vehicle class number.

(2) The normal class number is the largest bridge class number (single or dual) which permits the normal crossing of vehicles whose vehicle class numbers are equal to or less than the bridge class number.

(3) A special class number represents the load—carrying capacity of a bridge under special crossing conditions. These numbers are not posted on standard bridge marking signs, but on supplementary signs.

(4) Width requirements. See table 5-1.

Table 5-1. Bridge Width Requirements — *m (ft.)*.

Bridge class	4-12	13-30	31-60	61-100
one-lane width	2.74 (9)	3.35 (11)	<sup>4</sup> (13.2')	<sup>4.8</sup> (15.8')

- (1) For prefabricated bridges and ferries, bridge signs indicate the class number as given in technical manuals. For bridges fixed in place or for nonstandard fixed bridges designed in the field, bridge signs shall indicate the class number as determined by methods shown in chapter 7 or TM 5-312.
- (2) All single-lane bridge signs are a minimum of 16 inches in diameter. Multilane and dual class bridge signs are at least 20 inches in diameter. Numerals are black on a yellow background with a black border 1½ inches wide.

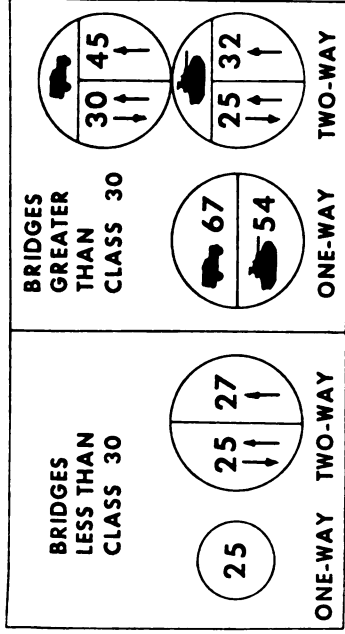


Figure 5-1. Bridge classification signs.

- (3) A multilane bridge has a road way wide enough to carry at least two lanes of traffic simultaneously. If each lane has the same class, the signs are the same as for single-lane bridges. If the lanes are of different classes, each lane has a class sign. Two-lane bridges may carry a combination circular sign (fig. 5-1) which gives the normal two-way classification on the left and the computed one-way classification on the right.
- (4) Dual classification is used for bridges with a capacity greater than class 30. Two numbers are then shown on the sign; the upper one for wheeled vehicles, the lower one for tracked vehicles (fig. 5-1). Dual class two-lane bridges may be designated by a composite sign indicating both dual class and combination classes (fig. 5-1).



c. *Traffic Control.* To expedite passage of vehicles and to prevent damage to the bridge, rigid control of bridge traffic must be maintained. This is done by the following control measures wherever possible.

(1) A traffic park is set up where vehicles can be halted and dispersed in order to avoid congestion. (fig. 5--2)

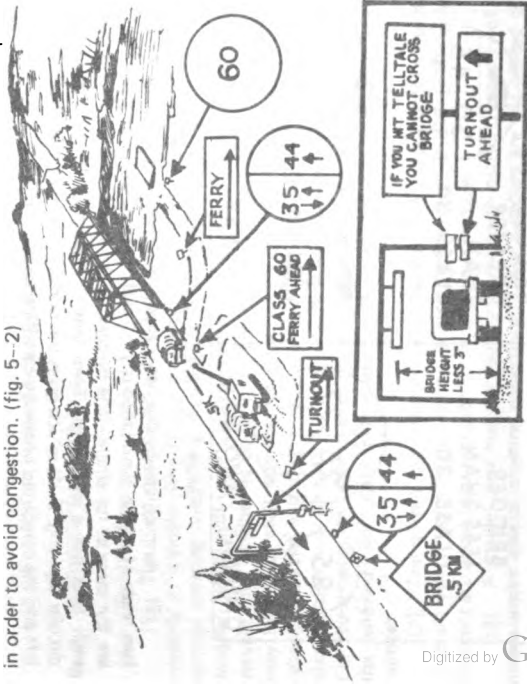


Figure 5-2. Example of telltale, turnout, and sign arrangement for single-lane bridges.

(2) A turnout area is provided for vehicles to turn off the road and out of the line of traffic. It is meant primarily for vehicles having mechanical troubles, but it can be used as a limited traffic park.

(3) Details are provided for bridges having overhead framing, trolley wires, or other features which limit overhead clearance.

(4) A normal crossing is defined as one in which the vehicle class number is equal to or less than the bridge classification number, where vehicles maintain 30.5-meter intervals, and where speed is restricted to 40 kph (25 mph). On floating bridge, sudden stopping or acceleration is forbidden.

(5) Special crossings are authorized by the local tactical commander, under exceptional operating conditions in the field. Special crossings permit a vehicle to cross a bridge (or other crossing means) whose class number is less than that of the vehicle. Special crossings are either caution crossings or risk crossings.

(a) In a caution crossing, vehicles with a classification exceeding the capacity of the bridge by 25 percent are allowed to cross under strict traffic control. Caution crossings require that the vehicle remain on the centerline, maintain a 50-meter distance from other vehicles, not exceed 12 kph (8 mph), not stop, not accelerate, and not shift gears on the bridge.

(b) A risk crossing may be made only on standard prefabricated fixed and floating bridges. Risk crossings are made only in the greatest emergencies. The vehicle moves on the centerline, is the only vehicle on the bridge, does not exceed 5 kph (3 mph), does not stop, does not accelerate, and does not shift gears on the bridge. The vehicle class number must not exceed the published risk class for the type bridge being crossed. After the crossing, and before other traffic is permitted, the engineer officer should reinspect the entire bridge for any damage.

## Section II. VEHICLES

### 5-2. MARKING OF VEHICLES

a. *Weight Classification.* All vehicles with a gross weight over 3 tons and all trailers with rated payload over 1½ tons are assigned classification numbers. These numbers indicate a relationship between the load-carrying capacity of a bridge and the effect produced on it by a vehicle. The effect of the vehicle on the bridge depends upon the gross weight of the vehicle, the weight distribution to the axles, and the speed at which the vehicle crosses the bridge.

b. *Vehicle Signs.*

(1) *Classification.* Classification numbers assigned to vehicles are whole numbers ranging from 4 through 150. Front signs on a vehicle are 9 inches in diameter and the side signs are 6 inches in diameter. The signs have black numerals on a yellow background and the numerals are as large as the sign will permit. The front sign goes above the bumper to the driver's right and below his line of vision, and the side sign on the right side of the vehicle in a place where normal use of the vehicle does not conceal it from view.

(2) *Combination Classification.* With a combination vehicle (two or more single vehicles spaced less than 30.5m apart), the front sign shows the normal vehicle class for the combination with the letter "C" in red above the class number. Each vehicle in the combination carries a side sign which shows its class as a single vehicle. If one vehicle is towing another, they are considered separate, unless they are both on the same span and the distance between them is less than 30.5m. Combination classes are determined as indicated in paragraph 5-3c below.

### 5-3. EXPEDIENT VEHICLE CLASSIFICATION

In an emergency, temporary vehicle classification can be accomplished by using expedient classification methods. The vehicle should be reclassified by the analytical method as outlined in TM 5-312 or by reference to FM 5-36 as soon as possible to obtain a permanent classification number.

a. *Wheeled Vehicles.* Expedient classification for wheeled vehicles may be accomplished by the following methods:

- (1) Compare the wheel and axle loadings and spacings of the vehicle with those of a classified vehicle of similar design and assign a temporary class number.

(2) Assign a temporary class number equal to 85 percent of the gross weight of the vehicle in tons as follows:

TEMPORARY CLASS (wheeled vehicles) =  $0.85 \text{ W.T}$   
 where W.T = gross weight of vehicle in tons.

weight of the vehicle may be estimated from the tire pressure and tire contact area if no other means are available.

$$W_T = \frac{A_T P_T N_T}{2000}$$

where,

$W_T$  = Gross weight of vehicle in tons

$A_T$  = Average tire contact area in square inches (tire in contact with hard surface)

$P_T$  = Tire pressure in PSI

$N_T$  = Number of tires

*Note:* The tire pressure may be assumed to be 75 psi for 2½-ton vehicles or larger if no tire gage is available. For vehicles having unusual load characteristics or odd axle spacings, a more deliberate vehicle classification procedure, as outlined in STANAG 2021, is required.

b. *Tracked Vehicles.* Expedient classification for tracked vehicles may be accomplished by the following methods:

- (1) Compare the ground contact area of the unclassified tracked vehicle with that of a previously classified vehicle to obtain a temporary class number.
- (2) Assign a temporary class number equal to the gross weight of the tracked vehicle in tons.

TEMPORARY CLASS (tracked vehicles) =  $W_T$

where,  $W_T$  = gross weight in tons

Tracked vehicles can be assumed to be designed for approximately 2,000 pounds (one ton) per square foot of their bearing area (most heavy vehicles are slightly less than this). Thus, the gross weight of the tracked vehicle ( $W_T$ ) can be estimated by measuring the total ground contact area of the tracks (square feet) and equating this to the gross weight in tons.

*Example:* An unclassified tracked vehicle has a ground contact area of 5,500 square inches. Therefore, the area is about 38.2 square feet, and the class of the vehicle is 38.2 or 39, since ground contact area is square feet equals approximate weight of a tracked vehicle in tons, which in turn is approximately equal to class number.

c. *Nonstandard Combinations.* The class number of nonstandard combinations of vehicles may be obtained expeditiously as follows:

Combination class =  $0.9 (A + B)$  if  $A + B$  60

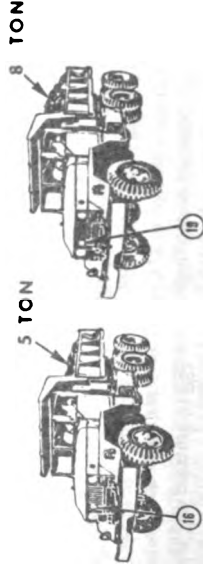
Combination class =  $A + B$  if  $A + B$  60

A = Class of first vehicle

B = Class of second vehicle

d. *Adjustment for Other Than Rated Load.* An expedient class may be given to overloaded or underloaded vehicles by adding to or subtracting the difference in loading, in tons, from the normally assigned vehicle class. The expedient classification number is marked with a standard vehicle class sign to indicate temporary classification as shown in figure 5-3.

## SINGLE VEHICLE EXPEDIENT CLASS OVERLOAD



**NORMAL CLASS + OVERLOAD = TEMPORARY CLASS**

$$16 + 3 = 19$$

Figure 5-3. Expedient class overload.

FLOATING EQUIPMENT

Section 1. BRIDGING AND RAFTING EQUIPMENT

**6-1. RIVER CROSSING EQUIPMENT**

See tables 6-1 thru 6-11.

**6-2. M4T6 DECK BALK DESIGN**

See fig. 6-1 and 6-2.

**6-3. OPERATING CHARACTERISTICS OF FLOATING EQUIPMENT**

See table 6-12.

**6-4. HELICOPTER EMPLOYMENT OF FLOAT MATERIAL**

See tables 6-13 and 6-14.

Table 6--1. River Crossing Equipment

EQUIPMENT	TRANS- PORTATION	PROPULSION	TYPE ASSEMBLY	TYPE CROSSING	CAPACITY OR CLASSIFICATION	ASSEMBLY TIME	REMARKS	
PNEUMATIC ASSAULT BOAT	W/1 2 1/2-TON TRUCK- 20 BOATS W/8 MEN- 1 BOAT.	11 PADDLES OR 25-HP OBM	MANUAL, W/ FURNISHED PUMPS (3)	PADDLE-ENGR CREW (3). OBM ENGR CREW (2).	15 MEN W/EQUIPMENT OR 3,375 POUNDS	10 MIN	FULLY LOADED MAINTAINS HEADWAY BY PADDLES IN 5 fps CURRENT; BY OBM, IN 11 fps CURRENT	
ENGINEER RECON BOAT	ONE MAN, BY BACKPACK	PADDLES (3)	MANUAL, W/ FURNISHED PUMPS (3)	PADDLE-ENGR CREW (3)	3 MEN W/EQUIPMENT OR 600 POUNDS	5 MIN	FULLY LOADED MAINTAINS HEADWAY IN 4 fps CURRENT	
ARMORED PERSONNEL CARRIER	SELF- PROPELLED	SELF- PROPELLED			12 MEN W/EQUIPMENT		ORGANIC ARMORED AND MECH INF UNITS	
BRIDGE ERECTION BOAT	ONE 2 1/2-TON W/ POLE TRAILER/BOAT	SELF- PROPELLED (TWO 90 HP MARINE DRIVE ENGINES)			9 MEN W/EQUIPMENT OR 3,000 POUNDS	20 MIN (TRANS- PORTED IN TWO SECTIONS)	PRIMARY USE IS HEAVY FLOATING BRIDGE ASSEMBLE AND RAFT PROPULSION	
ALUMINUM FOOTBRIDGE	TWO 2 1/2-TON TRUCKS W/TWO POLE TRAIL- ERS/ SET	PADDLED OR OBM	BRIDGE		STEAM VELOCITY fps		15 MIN SITE PREPARA- TION 1 1 MIN FOR EACH 15 FT OF BRIDGE	ANCHORED BY EXPEDIENT OVERHEAD CABLE BRIDLE LINE SYSTEM
					0.8	8.11		
				DAY	75 MEN/ MIN	60 MEN/ MIN		
				MOONLIGHT	40 MEN/ MIN	32 MEN/ MIN		
				BLACKOUT	25 MEN/ MIN	20 MEN/ MIN		
					1/4 TON 1 TRAILER 5fps	10 MIN		

Table 6-1. River Crossing Equipment (cont)

EQUIPMENT	TRANSPORTATION	PROPULSION	TYPE ASSEMBLY	TYPE CROSSING	CAPACITY OR CLASSIFICATION							ASSEMBLY TIME	REMARKS
LIGHT TACTICAL RAFT/BRIDGE	TWO 2 1/2-TON TRUCKS AND ONE POLE	MINIMUM OF TWO 25-HP OBM  ONE OUT-BOARD MOTOR PER PONTON IS RECOMMENDED	RAFTS		STREAM VEL FPS								
					5	7	8	9	10	11			
			4 PONTON/3 BAY W/O ARTICULATORS	N	12	12	12	8	4	0	30 MIN	33' LOADING SPACE	
				R	14	14	14	12	8	4			
			4 PONTONS/3 BAY W/O ARTICULATORS	N	18	16	12	8	4	0	25 MIN	33' LOADING SPACE	
				R	20	20	16	12	8	4			
			4 PONTON/4 BAY W/ ARTICULATORS	N	10	10	10	6	2	0	35 MIN	44' LOADING SPACE	
				R	12	12	12	10	6	2			
			5 PONTON/5 BAY W/ ARTICULATORS	N	9	9	9	8	5	2	40 MIN	55' LOADING SPACE	
				R	11	11	11	11	9	6			
			5 PONTON/4 BAY W/ ARTICULATORS	N	16	14	11	8	5	2	35 MIN	55' LOADING SPACE	
				R	19	17	15	12	9	6			
			6 PONTON/4 BAY W/ ARTICULATORS	N	13	13	13	13	12	5	45 MIN	44' LOADING SPACE	
				R	15	15	15	15	15	11			
			6 PONTON/4 BAY W/O ARTICULATORS	N	19	19	19	19	12	6	40 MIN	44' LOADING SPACE	
				R	24	24	24	23	17	11			
			6 PONTON/5 BAY W/O ARTICULATORS	N	18	18	18	18	12	6	45 MIN	55' LOADING SPACE	
				R	22	22	22	22	17	11			
			BRIDGE	N	16	13	11	8	5	2	150 FT		
				C	18	15	12	9	6	3	PER HR		
	R	21	17	14	11	8	5						



Table 6-1. River Crossing Equipment (cont)

EQUIP- MENT	TRANS- PORTATION	PROPULSION	TYPE ASSEMBLY	TYPE CROSSING	CAPACITY OR CLASSIFICATION						ASSEMBLY TIME	REMARKS
M416 FLOATING BRIDGE RAFT	ONE BRIDGE TRUCK/ 15' OF BRIDGE		NORMAL BRIDGE		STREAM VELOCITY FPS						SEE TABLE 6-4	KEDGE ANCHORS SHOREGUYS OR COMBINATION OVERHEAD CABLE BRIDLELINE MAY BE USED FOR ANCHORAGE
					3	5	7	8	9	11		
				N	50 55	45 55	40 50	35 45	30 40	25 30		
				C	60 61	58 59	54 55	49 51	45 47	35 37		
				R	68 69	66 67	62 63	59 60	54 56	43 45		
				N	75 75	75 75	70 75	65 70	55 60	27 30		
	12 BRIDGE TRUCKS/SET WITH ACCESSORIES		REIN- FORCED BRIDGE	C	80 80	80 80	79 79	73 73	66 67	43 45		
				R	90 90	90 90	90 90	87 87	81 81	59 60		
		TWO BRIDGE ERECTION BOATS/RAFT	4 FLOAT NORMAL RAFT	N	50 55	50 55	45 50	40 45	35 40	30 35	2 1/4 HR*	51'8" LOADING SPACE <sup>5</sup>
				R	60 65	60 65	55 60	50 55	45 50	35 40		
			4-FLOAT REIN FORCED RAFT	N	50 55	50 55	50 55	45 50	40 45	35 40	2 1/4 HR	38'4" LOADING SPACE
				R	60 65	60 65	60 65	55 60	50 55	45 50		

Table 6-1. River Crossing Equipment (cont)

EQUIP- MENT	TRANS- PORTATION	PROPULSION	TYPE ASSEMBLY	TYPE CROSSING	CAPACITY OR CLASSIFICATION						ASSEMBLY TIME	REMARKS			
			5-FLOAT NORMAL RAFT	N	STREAM VELOCITY FPS						3 HR	64'8" LOADING SPACE  *ASSEMBLY TIME BASED ON 3 NCO'S & 30 EM 50' LOADING SPACE			
					3	5	7	8	9	11					
					55 60	55 60	50 55	45 50	40 45	35 40					
					65 70	65 70	60 65	55 60	50 55	45 50					
			5 FLOAT REIN. FORCED RAFT	N	60 65	60 65	60 65	55 60	55 60	45 50	3 HR				
					70 75	70 75	70 75		65 70	55 60					
					65 70	65 70	65 70	65 70	60 65	45 50					
					75 80	75 80	75 80	75 80	70 75	55 60					
			6 FLOAT REIN. FORCED RAFT	N	65 70	65 70	65 70	65 70	60 65	45 50	3 3/4 HR		53'4" LOADING SPACE		
					75 80	75 80	75 80	75 80	70 75	55 60					
					62	62	55	55						500 FT/HR	NEED ONLY MAB CREW FOR ASSEMBLY 6 DISTRIBUTED LOADCAP 36 SHORT TONS 54 SHORT TONS 72 SHORT TONS  98 SHORT TONS  108 SHORT TONS
					36	36	36	36	36	36				6 MIN	
47	47	47	47	47	47	8 MIN									
60 62	60 62	60 62	60 62	60 62	60 62	10 MIN									
60 62	60 62	60 62	60 62	60 62	60 62	12 MIN									
60 62	60 62	60 62	60 62	60 62	60 62	12 MIN									
NOTE: MAB CLASS SHOULD BE REDUCED BY 30% IN CURRENT ABOVE 11 FPS.															

EQUIP MENT	TRANS- PORTATION	PROPUL- SION	TYPE ASSEMBLY	TYPE CROSSING	CAPACITY OR CLASSIFICATION							ASSEMBLY TIME	REMARKS
RIBBON BRIDGE/ RAFT	1 EA. M812 TRANS- PORTER WILL ACCOM- MODATE EITHER 1 EA. INTERIOR BAY, 1 EA. RAMP BAY, OR 1 EA. 27' BRIDGE ERECTION BOAT.		NORMAL BRIDGE	N	STREAM VELOCITY FPS							5 MIN/BAY	ANCHORAGE MAY BE BY TRANSPORTER OR EREC- TION BOATS (TEMPORARY). SEE TABLE 6-10) OR BY METHODS DESCRIBED FOR CLASS 60 OR M476 AS OUTLINED IN CHAPTER 10 TM 5-210. CLASSES GIVEN ARE FOR TRACKED VEHICLES.
					3	5	7	8	9	1'			
				C	65	65	60	60	45	-			
					70	70	65	65	50	-			
		2 BRIDGE ERECTION BOATS	3-BAY LONGITU- DINAL	N	45	45	40	35	30	25	5 MIN/BAY	44' LOAD SPACE	
			4-BAY LONGITU- DINAL	N	60	60	60	60	55	45		66' LOAD SPACE	
			5-BAY LONGITU- DINAL	N	70	70	70	70	60	50		88' LOAD SPACE	
			3-BAY CONVEN- TIONAL	N	45	35	15	10	-	-		22' LOAD SPACE	
		(*)3 BRIDGE ERECTION BOATS	4-BAY CONVEN- TIONAL	N	60	60	(*) 40	(*) 30	(*) 15	-		44' LOAD SPACE	
			5-BAY CONVEN- TIONAL	N	70	70	(*) 45	(*) 30	(*) 20	-		66' LOAD SPACE	

*Table 6-1. River Crossing Equipment (cont)*

<sup>1</sup>ALL ASSEMBLY TIMES ARE ESTIMATED USING TRAINED TROOPS, IN GOOD WEATHER, IN DAYLIGHT. FOR UNTRAINED TROOPS ADD 30%; FOR INCLEMENT WEATHER (40°, 80°, RAIN OR SNOW) ADD 30%; FOR BLACKOUT CONDITIONS ADD 50%. ALL PERCENTAGES CALCULATED FROM ORIGINAL TIME. EX. AT NIGHT WITH UNTRAINED TROOPS = 180% OF GIVEN TIME.

<sup>2</sup>ALL ASSEMBLY TIMES EXCLUDE SITE PREPARATION.

<sup>3</sup>CLASSIFICATION WHEELED VEHICLE/TRACKED VEHICLE.

<sup>4</sup>LTR LOADING SPACE MEASURED FROM END OF NEAR SHORE BAY TO END OF FAR SHORE BAY (EXCLUDES RAMP SECTIONS).

<sup>5</sup>M4T6 LOADING SPACE MEASURED FROM NEAR SHORE END STIFFENER TO FAR SHORE END STIFFENER (EXCLUDES END RAMPS).

<sup>6</sup>DISTRIBUTED LOAD CAPACITY IS THE WEIGHT IN SHORT TONS THAT CAN BE CARRIED BY THE RAFT.

<sup>7</sup>CLASSIFICATION OF MAB REFERS TO HEAVIEST VEHICLE WHICH CAN BE LOADED RESTRICTED BY END RAMP CLASSIFICATION.

Table 6--2. Aluminum Footbridge Data

BRIDGE SET	BASIS OF ISSUE	SUGGESTED WORKING PARTY		
		DETAIL	NCO	EM
NORMAL ASSEMBLY 472 FT 6 IN LIGHT VEHICLE BRIDGE: 100 FT EXPEDIENT RAFTS: 3 MAJOR ITEMS: PONTONS: 42 TREADWAYS: 42	ONE SET TO EACH ENGINEER FLOAT BRIDGE COMPANY (CORPS)	NEAR-SHORE ANCHOR CABLE	1	6
		FAR-SHORE ANCHOR CABLE		7
		BRIDLE LINE	1	2
		GUY LINE		5
		SHORE ASSEMBLY	1	6
		ASSEMBLY CARRYING		6
		RIVER ASSEMBLY	1	4
		HANDRAIL		3
		PLUS 2 EM PER 100 FT OF BRIDGE		

Table 6--3. Light Tactical Raft Data

BRIDGE SET	BASIS OF ISSUE	SUGGESTED WORKING PARTY		
		DETAIL	NCO	EM
ASSEMBLY AS BRIDGE: 44 FT OF LIGHT VEHICULAR BRIDGE ASSEMBLY AS RAFT: <b>ONE 4-PONTON</b> 4-BAY OR ONE 4-PONTON 3- BAY RAFT	TWO SETS TO EACH DIV ENGR BN. SIX SETS TO CORPS FLOAT BRIDGE COMPANIES.	RAFT OR BRIDGE	1	10
		PONTON CARRYING		10*
		DECK PANEL CARRYING	1	6
		PONTON CONNECTING		2
		PONTON DELIVERY	1	5
		DECK PANEL UNLOADING		
		BRIDGE ONLY	1	4
		BRIDGE CONNECTING		8
		NEAR SHORE ABUTMENT	1	12
		FAR SHORE ABUTMENT		12
		ANCHORAGE SYSTEM	2	

\*SAME PERSONNEL CAN BE USED FOR PONTON  
AND DECK PANEL CARRYING CREWS.

BRIDGE SET	BASIS OF ISSUE	SUGGESTED WORKING PARTY		
		DETAIL	NCO	EM
ONE NORMAL FLOAT- ING BRIDGE, 141 ft 8 IN, OR ONE 4-FLOAT AND 1 5-FLOAT REIN- FORCED RAFT, OR TWO FLOATING BRIDGES, 75 FT, ONE WITHOUT REINFORC- ING BALK ON END FLOAT, OR THREE 38-FT 4-IN FIXED SPANS.	DIVISIONAL ENGINEER BN FLOAT BRIDGE CO, 4 SETS. CORP'S ENGINEER FLOAT BRIDGE CO, 5 SETS	FLOAT INFLATION	1	5
		SADDLE ASSEMBLY (W/CRANE)	1	5
		SADDLE ASSEMBLY W/O CRANE)	2	20
		ASSEMBLED FLOAT DELIVERY	2	4
		BALK CARRYING	2	40
		BALK PLACING	1	12
		ANCHORAGE *	2	12
		NEAR SHORE ABUTMENT*	1	5
		FAR SHORE ABUTMENT*	1	5
		*NEEDED FOR BRIDGE ONLY		

Table 6-5. M4T6 Bridge Assembly Time

Length (Feet) (Normal Assembly)	Recommended Unit Size	Number of Assembly Sites	Time (Hours)
150	1 Company	2	4
200	"	2	5
250	"	2	6
300	2 Companies	3	4
350	"	3	5
400	"	4	5½
500	"	5	6
800	3 Companies	6	4
700	"	6	5-7
800	"	6	6-8
1000	"	6	7-10
1200	"	6	8-12

NOTE: See figure 6-1 for deck balk layout pattern.

Table 6-6. Deck Balk Fixed Span Data

Capacity For Specified Span Length (Ft) And Deck/Roadway Ratio															
Type Crossing	23'4"	30'0"				38'4"				45'0"					
	22 18	22 18	22 18	24 18	22 18	22 16	24 18	26 18	20 16	22 18	22 16	24 18	24 16	26 18	28 16
Normal	125	85	90	90	45	50	55	65	24	24	30	30	40	40	45
	100	65	70	70	35	40	45	50	25	25	30	30	35	35	40
Caution	120	100	100	105	70	70	75	82	40	46	46	51	51	56	56
	100	80	80	85	51	51	55	50	35	40	40	43	43	46	46
Risk	120	110	110	115	78	78	85	90	47	54	54	60	60	66	66
	100	90	90	95	57	57	62	67	40	45	45	49	49	53	53
Component Parts <sup>2</sup>	Number Of Parts Needed For Assembly														
Normal Balk	22	33	33	36	44	44	48	52	50	55	55	60	60	66	66
Short Balk	22	11	11	12	22	22	24	26	10	11	11	12	12	13	13
Tapered Balk <sup>1</sup>	36	47	43	48	36	32	36	36	42	47	43	48	44	49	45
Balk Connecting Stiffener	4	5	5	5	6	6	6	6	7	7	7	7	7	7	7

<sup>1</sup> Figure includes two complete ramps<sup>2</sup> All complete spans also require 4 bearing plates, 4 long cover plates, and 4 short cover plates<sup>3</sup> See figure 6-2 for deck balk layout pattern

OVERALL LENGTH*	42'3"
OVERALL WIDTH*	12'
HEIGHT*	12'
WEIGHT (TONS) - INTERIOR BAY	23.25
WEIGHT (TONS) - END BAY	25.80
TURNING RADIUS*	40'
SPEED -- LAND TRAVEL	42 MPH
LENGTH - INTERIOR BAY	26'
LENGTH - END BAY	36'
RAMP ARTICULATION ABOVE HORIZONTAL BELOW HORIZONTAL	ANY 6'3"

\* REFERS TO BRIDGE TRANSPORTER

COMPONENTS	215 M (700') OF CLASS 60 BRIDGE OR 6 EA. 7-BAY RAFTS, OR ANY COMBINATION OF 30 INTERIOR BAYS AND 12-RAMP BAYS.
BASIS OF ISSUE	ONE SET TO EACH RIBBON BR CO
ROADWAY WIDTH	4.1 M (13'6") PLUS 2 EA. 1.2 M (4') WALKWAYS
INTERIOR BAY - LENGTH WIDTH WEIGHT	6.7 M (22') 8.1 M (26'6") 4,631 KG (10,210 LBS)
RAMP BAY - LENGTH WIDTH WEIGHT	5.6 M (18'4") 8.1 M (26'6") 4,445 KG (9,800 LBS)
SITE CONSIDERATIONS WATER DEPTH BANK HEIGHT SHORE SLOPE	$\leq$ 112 CM (44") $\leq$ 1.5 M (5') $\leq$ 20%



Table 6-9. Ribbon Bridge Assembly Data

BRIDGE LENGTH (APPROX) METERS	FEET	BRIDGE BAYS		LAUNCHING SITES DESIRED	BRIDGE ERECTION BOATS	
		RAMP	INTERIOR		NEEDED	DESIRED
18	58	2	1	2	3	3
24	80	2	2	2	3	4
31	102	2	3	2	4	4
38	124	2	4	2	4	5
45	146	2	5	2	5	5
51	168	2	6	3	5	6
58	190	2	7	3	6	6
65	212	2	8	3	6	7
71	234	2	9	3	6	7
78	256	2	10	3	7	7

## NOTES

1. The number of boats shown in "Needed" column is based on an average stream velocity of about 0.91 to 1.5 meters (3 to 5 feet) per second.
2. Stream velocities determine the number of bridge erection boats to be added for a given increase in bridge length (number of interior bays added).
3. Safety boats are included; backup boats are not included.

VELOCITY	
MPS	FPS
0 to 0.9	0 to 3
0.9 to 1.8	3 to 6
1.8 to 2.4	6 to 8

INTERIOR BAYS ADDED
Up to 6
Up to 3
Up to 3

BOATS NEEDED
1
1
1

Table 6-10. Ribbon Bridge—Bridge Erection Boats Used for Short-Term Anchorage

STREAM VELOCITY		RATIO OF ERECTION BOATS TO INTERIOR BAYS	SPACING BETWEEN BOATS	
MPS	FPS		METERS	FEET
0-0.91	0-3	1:6	40	132
.91-1.8	3-6	1:4	27	88
1.8-2.4	6-8	1:3	20	66
Over 2.4	Over 8	As required	As required	As required

NCOIC	BRIDGE ON RAFT LENGTH (Number of Bars)															SUPERVISES ENTIRE OPERATION
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	
CREW	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	
MOTOR PARK	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	PREPARES TRANSPORTERS/ BAYS/BOATS FOR LAUNCH- ING; PARKS TRANSPORTERS AFTER LAUNCH; CONTROLS TRAFFIC IN PARK.
SHUTTLE	0	3	0	4	0	5	0	7	0	9	0	12	0	15	0	DRIVES TRANSPORTERS TO LAUNCHING SITES AND LAUNCHES BAYS/BOATS. (SEE NOTE 1.)
LAUNCHING	1	2*	1	2*	1	2*	1	2*	1	2*	1	2*	1	2*	1	ASSISTS IN BAY/BOAT LAUNCHING.
BRIDGE BOAT	1	9	1	9	1	12	1	15	1	18	1	21	1	24	1	OPERATES BRIDGE EREC- TION BOATS WITH THREE MEN ASSIGNED TO EACH BOAT TO SECURE BAYS AND ASSISTS IN THE ASSEMBLY AND DISASSEMBLY OF BRIDGE OR RAFT. (SEE NOTE 2.)
ANCHORAGE	2	12	2	12	2	12	2	12	2	12	2	12	2	12	2	INSTALLS ANCHOR CABLES, BRIDLE LINES, ANCHOR TOWERS, DEADMEN, AND SHORE GUYS.
BRIDGE CENTER LINE/RAFT /ASSY SITE	1	4	1	4	1	4	1	4	1	4	1	4	1	4	1	CONNECTS BAYS, PREPARES BRIDGE FOR TRAFFIC, DIRECTS USE OF TRANS- PORTERS WHEN USED FOR BRIDGE CLOSURE OR ANCHORAGE. (SEE NOTE 3.)
TOTAL	6	33	6	34	6	38	6	43	6	49	6	55	6	61	6	67

## NOTES:

1. DURING LAUNCHING AND RETRIEVING OPERATIONS, AN ASSISTANT OPERATOR IS ASSIGNED TO EACH TRANSPORTER.
2. DOES NOT INCLUDE PERSONNEL FOR SAFETY BOATS OR BACKUP BOATS.
3. EM MAY BE INCREASED TO SIX, DEPENDING ON LENGTH OF BRIDGE AND VELOCITY OF STREAM.
  - TWO LAUNCHING SITES.
  - THREE LAUNCHING SITES

## NEAR SHORE

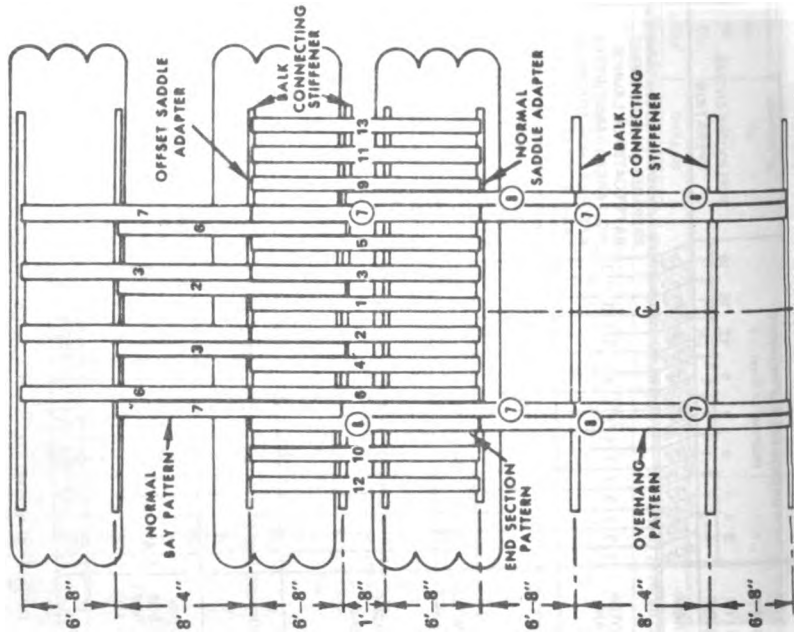
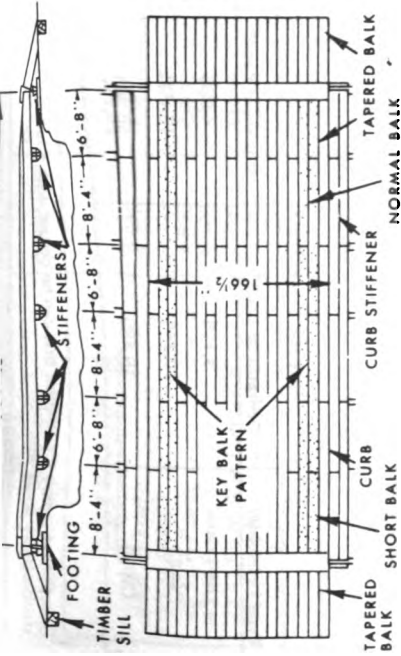
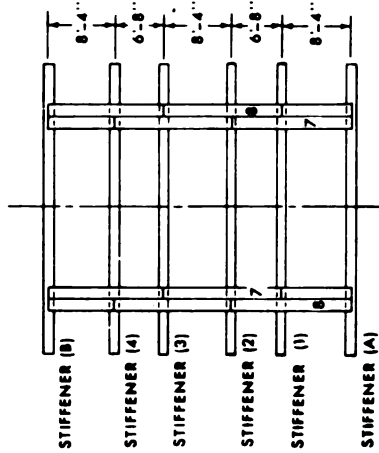


Figure 1 Bulk pattern, M4Tn floating bridge.



# ① LAYOUT



# ② H - FRAME FOR BALK FIXED SPAN

Figure 6-2. Layout of deck balk fixed bridges.

Table 6-12. Round-Trip Travel Times

Equipment	Time in Min Per Round Trip		
	Stream Width in Feet		
	250	500	1000
Pneumatic assault Boat - Paddled	4	6	10
Pneumatic assault Boat - Outboard Motors	-	4	5
Ribbon Bridge/Raft	7	10	15
M4T6/LTR	7	10	15
Mobile assault bridge	7	10	15

\*No. of rafts that can be used efficiently at one time =  $250' - 1, 500' - 2, 1000' - 3$ .

Table 6-13. Helicopter Capabilities

Type Helicopter	Helicopter Capability	
	Operational Load <sup>1</sup>	Maximum Load <sup>2</sup>
UH-1	3,116	4,000
CH-47	10,144	16,000
	15,400	20,760

<sup>1</sup>Operational payload is the amount that can be carried with a full fuel load on a sea level.

<sup>2</sup>Load without structurally damaging

Item of Equipment	Weight (lbs)	Recommended Carrier
<u>M4T6 FIXED SPANS</u>		
23'4" H-Frame	2,800	UH-1
30' H-Frame	3,700	CH-47
38'4" H-Frame	4,500	CH-47
45' H-Frame	5,100	CH-47
23'4" Fixed Span Complete <sup>1</sup>	12,900	CH-54
30' Fixed Span Complete <sup>1</sup> (Load No. 48) <sup>2</sup>	15,600	CH-54
38'4" Fixed Span Complete <sup>1</sup> (Load No. 49) <sup>2</sup>	18,800	CH-54
45' Fixed Span Complete <sup>1</sup>	20,900	CH-54
Single Trestle w/Bracing	3,400	UH-1
15' Trestle Arrangement		
w/22 Normal Balk (Load No. 57) <sup>2</sup>	11,800	CH-54
w/11 Normal Balk	8,100	CH-47
8'4" Trestle Arrangement		
w/22 Short Balk	9,500	CH-47
w/11 Short Balk	8,000	CH-47
<u>HEAVY FLOATING BRIDGE EQUIPMENT</u>		
27' Bridges Erection Boat	6,800	CH-47
(Load No. 61) <sup>2</sup>		
Bow Section	1,150	
Stern Section		
w/Fuel + Water	5,650	CH-47
w/o Fuel + Water	4,900	CH-47
Aluminum Balk		
Light Bundle (35 Normal Balk)	7,900	CH-47
(Load No. 51) <sup>2</sup>		
Heavy Bundle (63 Normal Balk)	14,200	CH-54
(Load No. 52) <sup>2</sup>		
Normal Balk (ea)	225	
Short Balk (ea)	122	
Tapered Balk (ea)	100	

Table 6-14. Typical Loads and Helicopter Requirements (cont)

Item of Equipment	Weight (lbs)	Recommended Carrier
M4T6 Float w/Saddle Assembly and Stiffeners (Load No. 53) <sup>2</sup>	6,700	CH-47
M4T6 Float w/Saddle Assembly, Stiffeners and 22 Normal Balk (Load No. 53) <sup>2</sup>	11,700	CH-54
Two M4T6 Floats w/Saddle Assemblies, Stiffeners, and 10 Normal Balk (Load Nos. 55, 56) <sup>2</sup>	16,900	CH-54
<u>LIGHT FLOATING BRIDGE EQUIPMENT</u>		
Light Tactical Raft		
Ponton Load (8 Half Pontons w/Cradle) (Load No. 58) <sup>2</sup>	6,000	CH-47
Deck Load (4 Bays Complete w/Articulators (Load No. 60) <sup>2</sup>	10,500	CH-47
Aluminum Footbridge		
One Set (472'6") Crated	11,000	CH-54
One Set (472'6") Uncrated	9,100	CH-47
Pneumatic Assault Boat	250	
<u>RIBBON BRIDGE/RAFT</u>		
Interior Bay	10,210	CH-47
Ramp Bay	9,800	CH-47

<sup>1</sup> Information refers to 22/18 fixed span including 36 tapered balk for ramps and 4 bearing plates

Load No. refers to loads described in TM 55-450-11 "Helicopter External Loads"

## 6-5. BASIC CONSIDERATIONS

*Anchorage must be provided on float bridges to secure the bridges and keep them aligned. The selection of an anchorage system is influenced by the width of the river, its current, stage variation, debris flow, the river bed, embankments, and resources available. The anchorage system is designed to withstand the worst conditions anticipated. The basic anchorage systems used are shore guys, kedge anchors, a combination of both, and overhead cable-bridle line systems. The strongest standard method of anchoring a floating bridge is the overhead cable--bridle system supplemented by shore guys. When combinations of anchorage systems are used, the load cannot be divided between systems — one must supplement the other.*

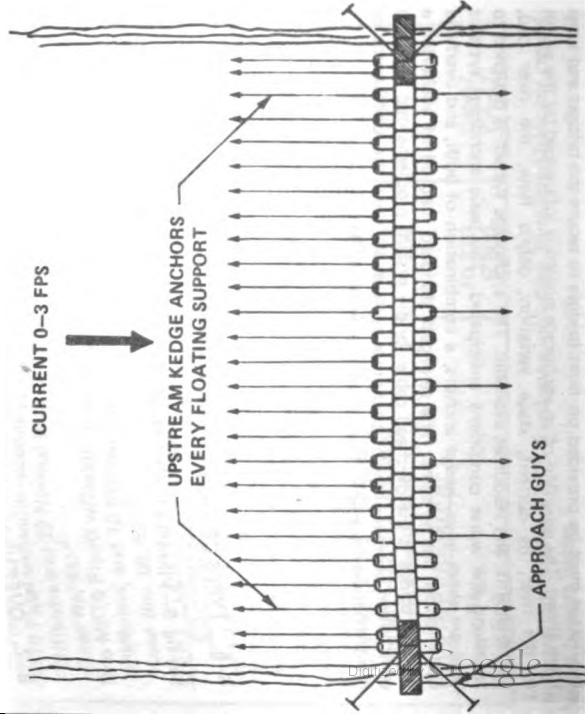
## 6-6. TYPES OF ANCHORAGE SYSTEMS

See fig. 6-3 thru 6-7 and table 6-15.

## 6-7. OVERHEAD CABLE-BRIDLE LINE SYSTEM DESIGN

*a. Anchor Cable Layout (fig. 6-8).*





**DOWNSTREAM KEDGE ANCHORS EVERY 3RD FLOATING SUPPORT.**

**EVERY FLOATING SUPPORT WITH REVERSAL CURRENT FROM 0 TO 3FPS**

CURRENT  
0-3FPS



DEADMEN LOCATED ABOVE  
HIGH WATER LEVEL TO  
PREVENT WASHOUT

UPSTREAM SHORE GUYS  
(EVERY 6TH FLOATING  
SUPPORT)

45°

APPROACH  
GUYS

SHORE GUYS CONSTRUCTED FROM NOT  
LESS THAN 1/2 INCH IPS WIRE ROPE

DOWNSTREAM SHORE GUYS EVERY 10TH FLOATING  
SUPPORT; (EVERY 6TH FLOATING SUPPORT IF  
REVERSAL CURRENT EXCEEDS 3FPS)

Figure 6 4 Location of shore guys

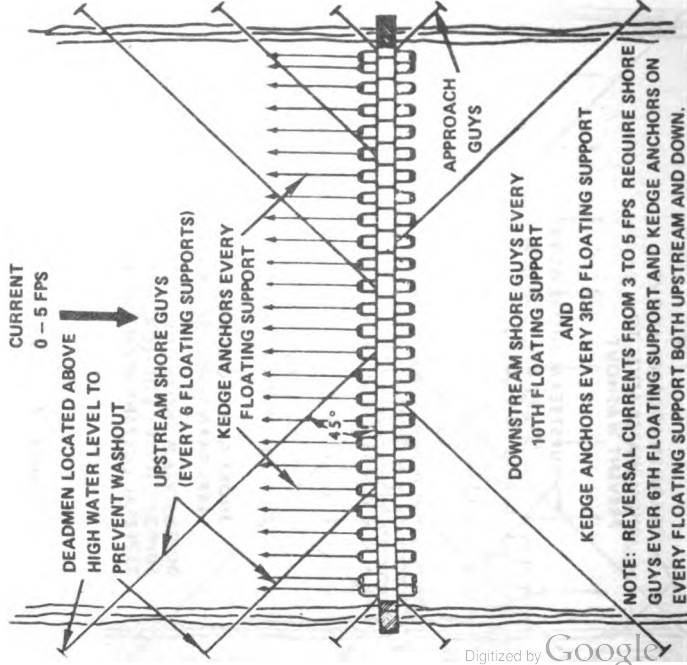
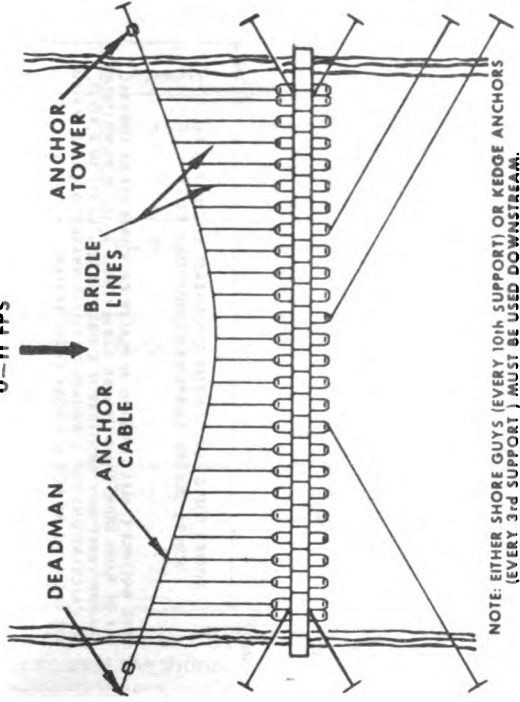


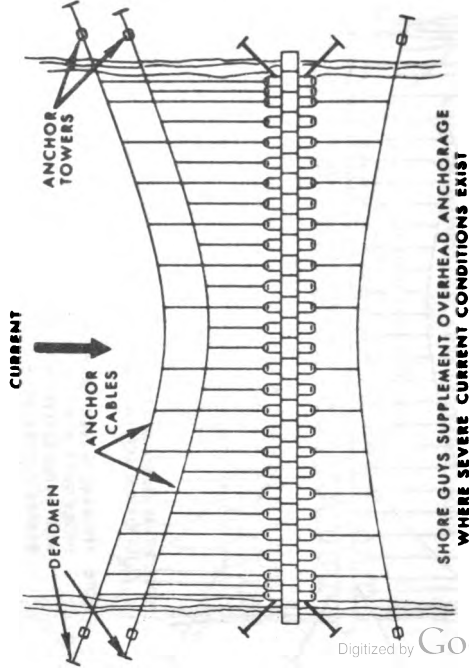
Figure 6-5. Employment of combination system.

CURRENT  
0-11 FPS



**NOTE: REVERSAL CURRENT MAY REQUIRE FULL ANCHORAGE DOWNSTREAM. SHORE GUYS, KEDGE ANCHORS, COMBINATION, OR SECOND CABLE BRIDLE LINE SYSTEM MAY BE USED, DEPENDING ON STRENGTH OF REVERSAL CURRENT.**

Figure 6--6. Single upstream overhead cable-bridle line system.



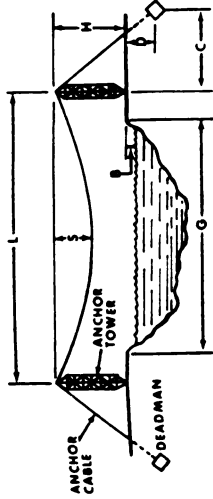
**NOTE: MULTIPLE CABLES CAN ALSO BE PLACED ON SINGLE SET OF TOWERS. USE OF MORE THAN ONE OVERHEAD CABLE (TABLE 6-16). A DOWNSTREAM ANCHOR CABLE MAY BE NEEDED IF A TIDAL ACTION EXISTS IN A RIVER. THE CALCULATIONS FOR A DOUBLE OR TRIPLE OVERHEAD CABLE SYSTEM ARE THE SAME AS FOR A SINGLE CABLE SYSTEM.**

**Figure 6-7. Floating bridge with multiple overhead cable system and downstream overhead cable anchorage**

*Table 6-15. Anchorage Systems/Characteristics*

Type	Capacity	Remarks
Kedge Anchors	0-3 fps	Anchor line must be a minimum of 10 times the depth of the water; 20 times depth is desirable. River bed must permit anchor flukes to dig in. See figure 6-3.
Shore Guys	0-3 fps	Guys attached at 45° angle. Shore anchorage point needed for guy lines (soil must hold dead-man). See figure 6-4.
Combina- tion Kedge & Shore Guys	0-5 fps	See remarks for separate systems. See figure 6-5.
Over- head Cable- Bridle Line	0-11fps	See para 6-7 for design. 1200 ft maximum unsupported cable length. See figure 6-6.

**NOTE:** All anchorage systems require approach guys to the floating supports nearest the shores.

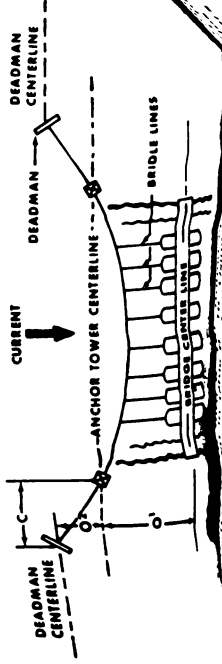


(1) ANCHOR CABLE—ELEVATION LAYOUT

## KEY TO SYMBOLS:

- B = MEAN BANK HEIGHT
- C = DISTANCE TOWER TO DEADMAN ON CENTERLINE
- D = DEPTH OF DEADMAN
- G = LENGTH OF BRIDGE
- H = ANCHOR TOWER HEIGHT
- L = DISTANCE BETWEEN TOWER ANCHOR
- O<sub>1</sub> = OFFSET BRIDGE CENTERLINE TO ANCHOR TOWER CENTERLINE
- O<sub>2</sub> = OFFSET ANCHOR TOWER CENTERLINE TO DEADMAN
- S = UNSTRESSED SAG IN ANCHOR CABLE
- R = GROUND BEARING STRENGTH IN POUNDS PER SQUARE FOOT
- T = CABLE TENSION IN POUNDS

(2) ANCHOR CABLE—BRIDLE LINE LAYOUT PLAN



1. Determine the size and number of anchorage cables that are required (tables 6-16 thru 6-18). Round up to the next higher value for bridge span (G) shown in table 6-16. Using known current or next higher stream velocity, select the cable size for the minimum number of cables.

(2) Determine the distance between towers (L). Place the towers the same distance from each bank.

Rule of Thumb (R of T);  $L = (1.1 \times \text{gap}) + 100'$

(3) Determine cable sag in feet (S) (fig. 6-8 and 6-9).

R of T;  $S = 0.02L$

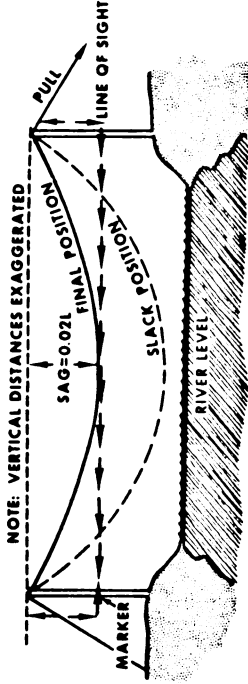


Figure 6-9. Cable sag.

(4) Determine required height of tower (H), when sag (S) and bank height (B) are known.

R of T;  $H = 3' + S - B$  (Minimum allowable H)

Note: Actual height of tower (H) will be the next higher size shown in table 6-19.

(5) Determine the distance from the bridge centerline to the anchor tower centerline ( $O_I$ ).

R of T

(a) If bank height (B) is less than 15';  $O_I = H + 50'$

(b) If (B) is greater than 15';  $O_I = H + B + 35'$



*Table 6--16. Anchor Cable Requirements for Overhead  
Cable-Bridle Line System – M4T6 Bridge*

Bridge Span (G) (ft)	Type Bridge Assembly	Size (IN.) and Number of Cables for Specified Stream Velocities*										
		5 fps			7 fps			9 fps			11 fps	
		Single	Dual	Triple	Single	Dual	Triple	Single	Dual	Triple	Single	Dual
200	Normal	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{3}{4}$
	Reinforced	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
400	Normal	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	1	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{1}{4}$	1
	Reinforced	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	1	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$
600	Normal	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	1	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$
	Reinforced	1	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{8}$	1	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{7}{8}$		$\frac{1}{2}$
800	Normal	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{7}{8}$	..	$\frac{1}{2}$
	Reinforced	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{7}{8}$	...	$\frac{3}{8}$	1	..	..

**Table 6-16. Anchor Cable Requirements for Overhead  
Cable-Bridle Line System – M4T6 Bridge (cont)**

BRIDGE SPAN (G) (ft)	TYPE  BRIDGE ASSEMBLY	SIZE (IN.) AND NUMBER OF CABLES FOR SPECIFIED STREAM VELOCITIES*											
		5 FPS			7 FPS			9 FPS			11 FPS		
		SINGLE	DUAL	TRIPLE	SINGLE	DUAL	TRIPLE	SINGLE	DUAL	TRIPLE	SINGLE	DUAL	TRIPLE
1000	NORMAL	1	7/8	3/4	1 1/4	1	7/8	1 1/2	1 3/8	1	**	**	1 1/4
	REINFORCED	1 1/4	1	3/4	1 1/2	1 1/4	1	**	**	1 1/8	**	**	1 3/8
100	NORMAL	1 1/8	7/8	3/4	1 3/8	1 1/8	7/8	**	1 1/2	1 1/8	**	**	1 3/8
	REINFORCED	1 3/8	1 1/8	7/8	**	1 3/8	1	**		1 1/4	**	**	**

BASED UPON IMPROVED PLOW STEEL CABLE AND 2 PERCENT INITIAL CABLE SAG.  
SAFE. BASED ON CABLE SPAN EQUAL TO 1.1 TIMES WET GAP PLUS 100 FEET.  
ASS 60 ANCHORAGE REQUIREMENTS ARE THE SAME AS M4T6. ROUND UP TO  
NEXT HIGHER BRIDGE SPAN.

Table 6-17. Anchor Cable Requirements -- Light Tactcal Bridge

Span in feet (Wet gap)	Maximum stream velocity (fps)			
	5	7	9	11
200	3 / 8	3 / 8	1 / 2	1 / 2
300	3 / 8	1 / 2	5 / 8	3 / 4
400	1 / 2	1 / 2	5 / 8	3 / 4
500	1 / 2	5 / 8	5 / 8	3 / 4
600	5 / 8	5 / 8	3 / 4	7 / 8

Table 6-18. Anchor Cable Requirements -- Aluminum Footbridge

CURRENT VELOCITY	TYPE ANCHORAGE	WHERE ATTACHED TO BRIDGE
STILL WATER	GUY LINE	MIDDLE OF TREADWAY STRINGER OF EVERY 3d BAY ON BOTH SIDES OF BRIDGE.
STILL WATER	ANCHOR CABLE W/BRIDLE LINES	THROUGH THE BOW OF THE PONTON TO THE TREADWAY STRINGER OF EVERY 3d BAY ON BOTH SIDES OF THE BRIDGE
3 FPS OR LESS	ANCHOR CABLE W/BRIDLE LINES	THROUGH THE BOW OF THE PONTON TO THE TREADWAY STRINGER OF EVERY 2d BAY ON BOTH SIDES OF THE BRIDGE

Number of Tower Sections	Height of Tower
Cap. base, and pivot unit	3 ft 8½ in
1	14 ft 6½ in
2	25 ft 4½ in
3	36 ft 2½ in
4	47 ft ¼ in
5	57 ft 10¼ in
6	68 ft 8½ in

**Note** Minimum of 3 ft 8½ in can be used as tower height.

c. *Deadman.*

(1) *Depth of deadman (D).* The deadman should be buried as deep as necessary for good bearing surface against undisturbed soil. R of T; D = 7' or 1' less than the depth of the water table — whichever is less. Minimum (D) = 3'. (D) is measured from the ground level to the mean depth of timber. See figures 6-10 and 6-11. (Always maintain at least 1 foot of undisturbed soil between the bottom of the deadman and the ground water level.)

(2) *Tower to deadman distance.* Determine tower to deadman distance (C) and deadman offset (O<sub>2</sub>). See figure 6-8.

(a) Select the approximate position for the deadman based upon site conditions.

(b)  $C = \frac{(H + D)}{\text{Slope Ratio}}$  : Minimum permissible value for C is H + D (slope ratio of 1/1). Try to let  $C = \frac{(H + D)}{1/4}$ .

(c) Read required value of O from table 6-20 (O<sub>2I</sub>) for C used. The actual value of O<sub>2</sub> (O<sub>2A</sub>) for a calculated value of C can be computed using the following formula:

$$O_{2A} = \frac{C}{100} \times O_{2I}/O_{2I} \text{ read from table 6-20}.$$

Table 6-20. Values of  $O_2$  Per Hundred Feet of C

Current velocities		Offset upstream ( $O_2$ ) in feet per hundred feet of C
Normal assembly	Reinforced assembly	
3 fps	—	9
5 fps	3 fps	11
7 fps	5 fps	14
9 fps	7 fps	17
11 fps	9 fps	19
—	11 fps	23

NOTE: Use current velocity known or next higher current to determine  $O_2$ .

(3) *Determine deadman size.* Determine lumber available and check length (L), thickness (t), and face height (f) or (d) of available timber. Use the largest dimension of the deadman timber for bearing and refer to it as the face height (f). The face height for a log deadman is its diameter (d) (fig. 6-10 thru 6-12).

(a) Enter nomograph "A" (fig. 6-13) at Column A with D and slope ratio (1/4).

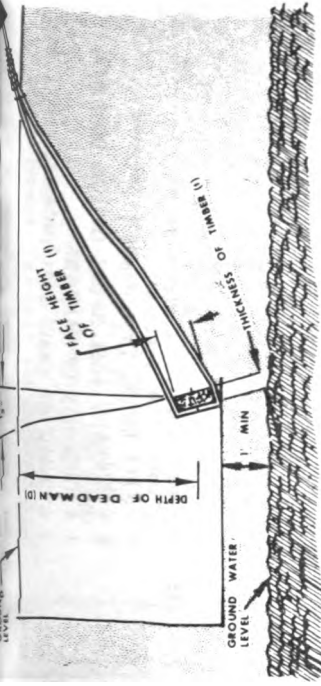
(b) Locate cable diameter and type on Column B. Connect the points from Column A to Column B and extend the line to Column C.

(c) Extend the line horizontally to the face height curve and read the deadman length and thickness from the top and/or bottom of the graph.

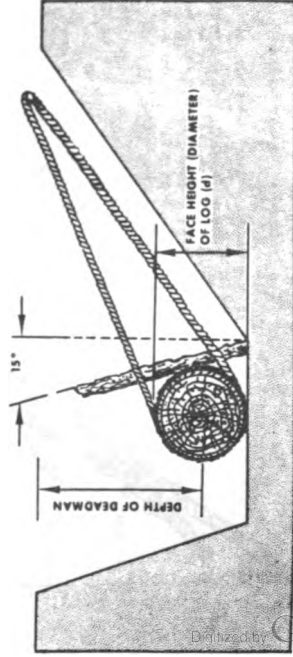
(4) *Bearing plate design.*

(a) *Flat bearing plate.* Enter nomograph "B" (fig. 6-14) with size and cable type. From the deadman face height curve, determine the bearing plate height, thickness, and length.

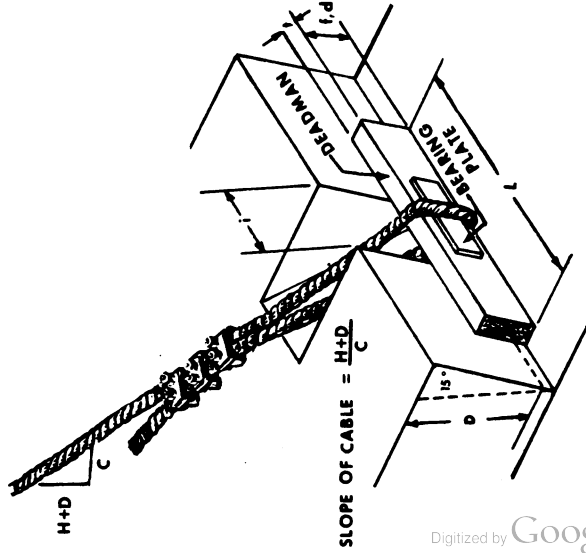
ENTER DEADMAN FACE HEIGHT "C" (fig. 6-15) WITH



*Figure 6-10. Timber deadman.*



*Figure 6-11. Log deadman.*



KEY:

D = MEAN DEPTH OF DEADMAN

L = LENGTH OF DEADMAN

f = FACE HEIGHT OF (TIMBER)

d = DIAMETER FACE HEIGHT OF LOG DEADMAN

t = THICKNESS OF DEADMAN

i = WIDTH OF CABLE SLOT (NORMALLY 1" — 0")

C = DISTANCE OF DEADMAN BEHIND TOWER

H = ACTUAL TOWER HEIGHT

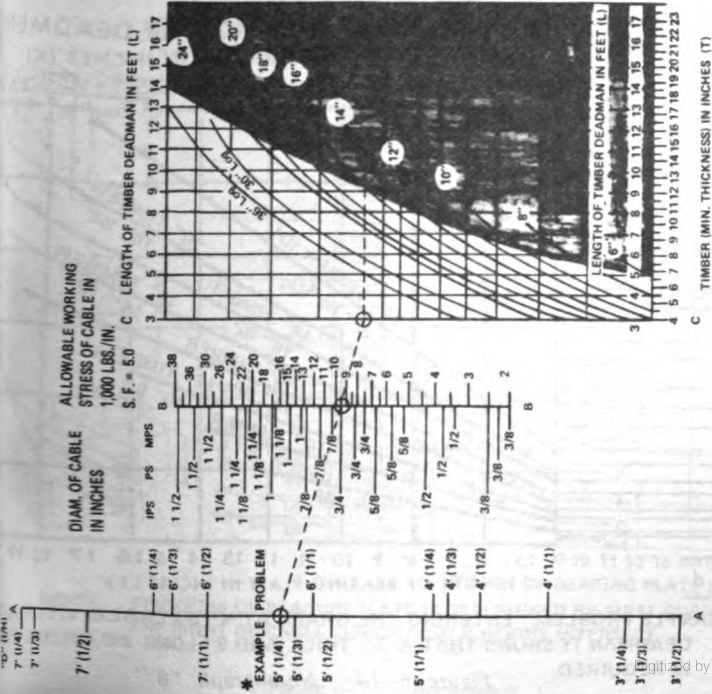


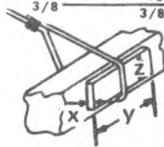
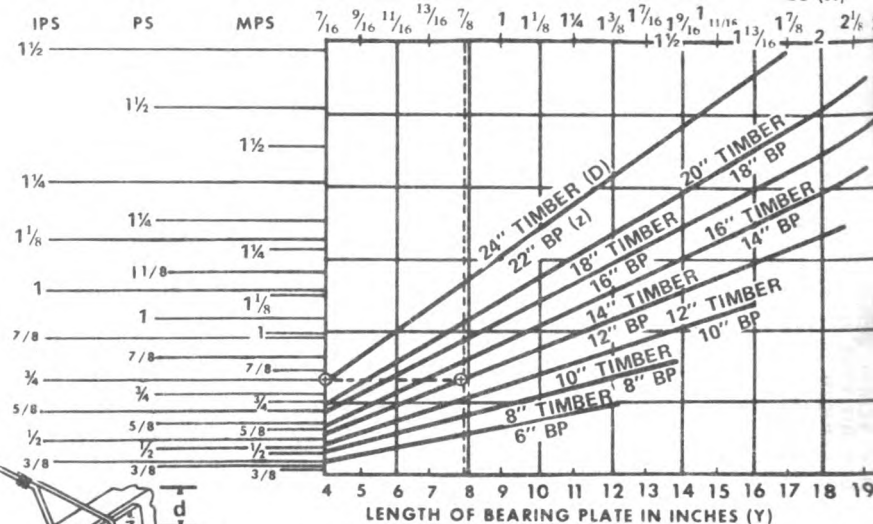
Figure 6-13. Nomograph "A."



# DESIGN OF FLAT BEARING PLATES FOR RECTANGULAR DEADMEN

DIAM. OF CABLE IN INCHES

THICKNESS OF BEARING PLATE IN INCHES (X)



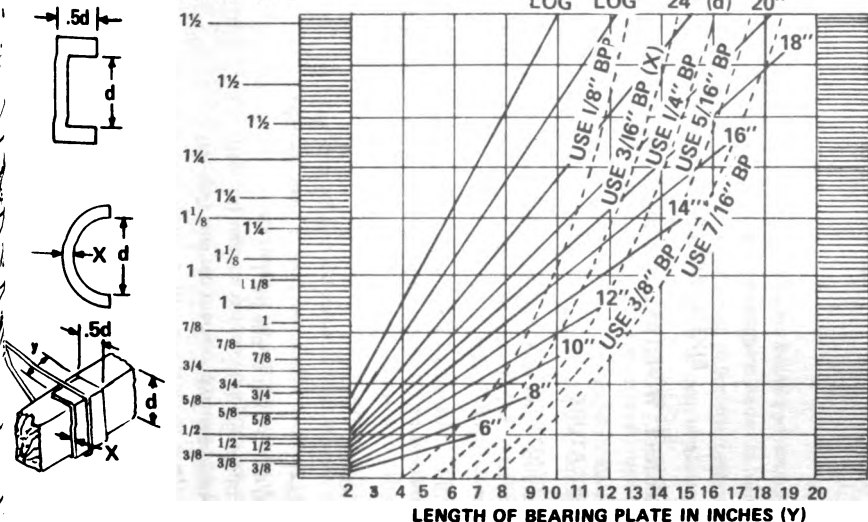
**SAMPLE PROBLEM:** ENTERING THE GRAPH AT 3/8" IPS CABLE WITH A DEADMAN IT SHOWS THAT A 7/8" THICK AND 8" LONG BEARING PLATE IS REQUIRED.

Figure 6-14. Digitized by Google

DIAM. OF CABLE IN INCHES

1PS PS MPS

36" 30"  
LOG LOG 24" (d) 20"



**NOTE:** THICKNESS OF BEARING PLATE IS DETERMINED BY FIRST CURVE TO THE RIGHT OF CABLE SIZE/DEADMAN HEIGHT INTERSECT

Figure 6-15. Nomograph "C"

## CHAPTER 7

## FIXED BRIDGES

## Section I. NONSTANDARD BRIDGE DESIGN

## 7-1. NOMENCLATURE

- a. *Superstructure.* The load-carrying component of the superstructure is the stringer system, which may be rectangular timber, round timber, or steel beams (figs. 7-1 and 7-2).
- b. *Substructure.* Intermediate supports for the superstructure may be timber bents, timber piers, pile bents, or pile piers, or a combination of these supports (fig. 7-1).

## 7-2. NOTATIONS

- A = Area (in<sup>2</sup>)
- A<sub>p</sub> = Bearing area of post or pile (in<sup>2</sup>)
- b = Width of stringer (in)
- b<sub>c</sub> = Width of corbel (in)
- b<sub>cap</sub> = Width of cap (in)
- b<sub>sill</sub> = Width of sill (in)
- B<sub>pl</sub> = Width of bearing plate (in)
- d = Total depth of stringer (in)
- d<sub>c</sub> = Depth of corbel (in)
- d<sub>cap</sub> = Depth of cap (in)
- D<sub>cap</sub> = Diameter of pile (in)
- D<sub>post</sub> = Diameter of timber bent post (in)

$L_c$	= Effective corbel length (ft)
$L_e$	= Effective span length (ft)
$L_{ftg}$	= Length of footing (in)
$L_m$	= Max span length (ft)
$L_{pL}$	= Length of bearing plate (in)
$M_{DL}$	= Dead load bending moment for entire span (kip--ft)
$M_{LL}$	= Live load bending moment per lane (kip--ft)
$m$	= Total bending moment per stringer (kip--ft)
$M_c$	= Total moment acting on the corbels
$m_{DL}$	= Dead load bending moment per stringer (kip--ft)
$m_{LL}$	= Live load bending moment per stringer (kip--ft)
$N_b$	= Number of braces
$N_c$	= Number of corbels
$N_L$	= Number of lanes
$N_p$	= Number of posts or piles
$N_{pr}$	= Theoretical number of piles required
$N_s$	= Number of stringers
$N_1$	= Effective number of stringers per lane
$N_2$	= Effective number of stringers per lane for a 2-lane bridge
$0$	= Diameter of pile (in)
$P_b$	= Capacity per pile based on end-bearing support
$P_f$	= Capacity per pile for friction support
$P_T$	= Total design load on substructure (kips)
$S_b$	= Maximum spacing of bracing (ft)
$S_x$	= Center to center spacing of component "x" (ft)
$t_{pL}$	= Thickness of bearing plate (in)

$V_c$	= Total shear acting on the corbels
$v_c$	= Shear capacity of one corbel
$V_{DL}$	= Dead load shear for entire span (kips)
$V_{LL}$	= Live load shear per lane (kips)
$v_{LL}$	= Total shear per stringer (kips)
$v_{DL}$	= Dead load shear per stringer (kips)
$v_{LL}$	= Live load shear per stringer (kips)
$W_R$	= Width of roadway from inside curb to inside curb (ft)
$W_S$	= Width of concrete slab (ft)

**ROUND OFF RULE:** Round the value down to the nearest whole number if the decimal is 0.09 or less, otherwise round up. Use this rule throughout where noted with an asterisk (\*).

### 7-3. SUPERSTRUCTURE DESIGN (Timber and Steel Stringers)

#### a. *Stringer Selection and Design.*

- (1) Step 1: Determine the maximum span length,  $L_m$ , of the stringers available from table 7-1 or table 7-2. Choose only those stringers with an  $L_m$  value  $\geq$  the span length.

**NOTE:** Designs computed in this chapter are not conservative.

- (2) Step 2: Determine the number of required stringers:

$$* N_s = \frac{W_R}{6} + 1 \quad (\text{Minimum } N_s = 4)$$

Determine the center-to-center stringer spacing:  
" "

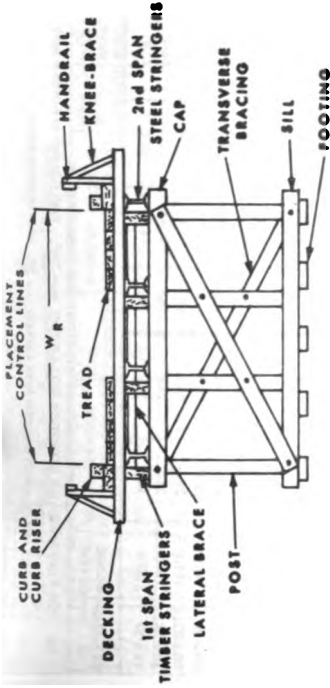


Figure 7-1. Timber trestle bridge.

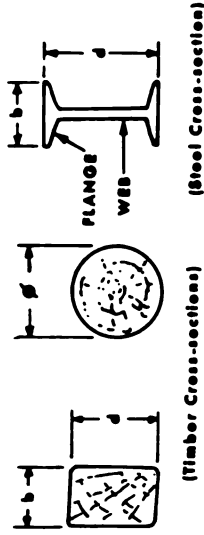


Figure 7-2. Stringer dimensions.

Table 7-1. Properties of Timber Stringers

ACTUAL SIZE (b x d) (in)	(a) MOMENT CAPACITY m (kip ft)	(b) SHEAR CAPACITY v (kips)	(c) MAXIMUM SPAN LENGTH (L <sub>m</sub> ) (ft)	ACTUAL SIZE (b x d) (in)	(a) MOMENT CAPACITY m (kip ft)	(b) SHEAR CAPACITY v (kips)	(c) MAXIMUM SPAN LENGTH (L <sub>m</sub> ) (ft)
4 x 8	8.53	3.2	9.5	12 x 20	160.0	24.0	23.8
• 4 x 10	13.33	4.0	11.9	12 x 22	193.6	26.4	26.2
• 4 x 12	19.20	4.8	14.3	12 x 24	230	28.8	28.6
6 x 8	12.80	4.8	9.5	14 x 14	91.5	19.6	16.7
6 x 10	20.0	6.0	11.9	14 x 16	119.5	22.4	19.1
6 x 12	28.8	7.2	14.3	14 x 18	151.2	25.2	21.5
• 6 x 14	39.2	8.4	16.7	14 x 20	186.7	28.0	23.8
• 6 x 16	51.2	9.6	19.1	14 x 22	226	30.8	26.2
• 6 x 18	64.8	10.8	21.5	14 x 24	269	33.6	28.6
8 x 8	17.07	6.4	9.5	16 x 16	136.5	25.6	19.1
8 x 10	26.7	8.0	11.9	16 x 18	172.8	28.8	21.5
8 x 12	38.4	9.6	14.3	16 x 20	213	32.0	23.8
8 x 14	52.3	11.2	16.7	16 x 22	258	35.2	26.2
8 x 16	68.3	12.8	19.1	16 x 24	307	38.4	28.6
• 8 x 18	86.4	14.4	21.5	18 x 18	194.4	32.4	21.5
• 8 x 20	106.7	16.4	23.8	18 x 20	240	36.0	23.8
• 8 x 22	129.1	17.6	26.2	18 x 22	290	39.6	26.2
• 8 x 24	153.6	19.2	28.6	18 x 24	346	43.2	28.6
10 x 10	33.3	10.0	11.9	8 $\phi$	10.05	5.7	9.5
10 x 12	48.0	12.0	14.3	9 $\phi$	14.31	7.2	10.7
10 x 14	65.3	14.0	16.7	10 $\phi$	19.63	8.8	11.9
10 x 16	85.3	16.0	19.1	11 $\phi$	26.1	10.6	13.1
10 x 18	108.0	18.0	21.5	12 $\phi$	33.9	12.7	14.3
10 x 20	133.3	20.0	23.8	13 $\phi$	43.1	15.0	15.5
10 x 22	161.3	22.0	26.2	14 $\phi$	53.9	17.4	16.7
10 x 24	192.0	24.0	28.6	16 $\phi$	80.4	22.6	19.1
12 x 12	57.6	14.4	14.3	18 $\phi$	114.5	28.6	21.5

## KEY TO SYMBOLS:

• DIAMETER

• LATERAL BRACING REQUIRED AT MID-POINT AND ENDS OF SPAN.

(a) FOR RECTANGULAR STRINGER NOT LISTED,  $m = \frac{bd^2}{30}$ . FOR ROUND STRINGER NOT LISTED,  $m = .02d^3$

(b) FOR RECTANGULAR STRINGER NOT LISTED,  $v = \frac{bd}{10}$ . FOR ROUND STRINGER NOT LISTED,  $v = .09d^2$

(c) FOR STRINGER NOT LISTED,  $L = 1.19d$

Table 7-2. Properties of Steel Stringers

NOMINAL SIZE	ACTUAL DEPTH (d) (in)	ACTUAL WIDTH (b) (in)	FLANGE THICKNESS (t <sub>f</sub> ) (in)	WEB THICKNESS (t <sub>w</sub> ) (in)	MOMENT CAPACITY m (kip-ft)	MOMENT CAPACITY v (kips)	MAX SPAN LENGTH (L <sub>m</sub> ) (ft)	MAX BRACING SPACING (S <sub>b</sub> ) (ft)
51BU278	51 1/4	14	1 5/8	3/4	3067	594	133	15
*36WF211	36 1/4	11 3/4	1 7/16	3/4	1770	450	100	15
*37WF206	37 1/4	11 3/4	1 7/16	3/4	1656	425	96	15
36WF300	36 3/4	16 5/8	1 11/16	15/16	2496	520	94	25.5
36WF194	36 1/2	12 1/8	1 1/4	13/16	1482	431	93	14
36WF182	36 3/8	12 1/8	1 3/16	3/4	1397	406	93	13
36WF170	36 1/8	12	1 1/8	1 1/16	1302	381	92	12
36WF160	36	12	1	11/16	1217	365	92	11.5
36WF230	35 7/8	16 1/2	1 1/4	3/4	1879	421	91	19.5
36WF150	35 7/8	12	15/16	5/8	1131	350	91	10.5
*36WF201	35 3/8	11 3/4	1 7/16	3/4	1545	402	90	16
33WF196	33 3/8	11 3/4	1 7/16	3/4	1433	377	86	17
33WF220	33 1/4	15 3/4	1 1/4	13/16	1661	392	85	20
33WF141	33 1/4	11 1/2	15/16	5/8	1006	313	85	11
33WF130	33 1/8	11 1/2	7/8	9/16	911	300	86	10
33WF200	33	15 3/4	1 1/8	3/4	1506	362	84	18.5
*31WF180	31 1/2	11 3/4	1 5/16	11/16	1327	327	80	16.5
30WF124	30 1/8	10 1/2	15/16	5/8	797	273	77	11
30WF116	30	10 1/2	7/8	9/16	738	263	76	10
30WF108	29 7/8	10 1/2	3/4	9/16	672	255	76	9
*30WF175	29 1/2	11 3/4	1 5/16	11/16	1156	304	75	17.5
*27WF171	27 1/2	11 3/4	1 5/16	11/16	1059	282	70	18.5
27WF102	27 1/8	10	13/16	1/2	599	217	69	10
27WF94	26 7/8	10	3/4	1/2	546	205	68	9
*26WF157	25 1/2	11 3/4	1 1/4	5/8	915	237	65	19



Table 7-2. Properties of Steel Stringers (Con't)

NOMINAL SIZE	ACTUAL DEPTH (d) (in)	ACTUAL WIDTH (b) (in)	FLANGE THICKNESS (t <sub>f</sub> ) (in)	WEB THICKNESS (t <sub>w</sub> ) (in)	MOMENT CAPACITY m (kip-ft)	MOMENT CAPACITY v (kip-s)	MAX SPAN LENGTH (L <sub>m</sub> ) (ft)	MAX BRACING SPACING (S <sub>b</sub> ) (ft)
24WF94	24 1/4	9	7/8	1/2	497	191	62	11
24WF84	24 1/8	9	3/4	1/2	442	174	61	9.5
24WF100	24	12	3/4	1/2	560	173	61	13
24I120	24	8	1 1/8	1 3/16	564	286	61	12.5
24I106	24	7 7/8	1 1/8	5/8	527	224	61	12
24I80	24	7	7/8	1/2	391	183	61	8.5
24WF76	23 7/8	9	11/16	7/16	394	163	61	8.5
*24WF153	23 5/8	11 3/4	1 1/4	5/8	828	217	60	20.5
*24I134	23 5/8	8 1/2	1 1/4	13/16	634	283	60	15
*22I75	22	7	13/16	1/2	308	168	56	8.5
*21WF39	21 5/8	11 3/4	1 3/16	5/8	699	198	55	24.5
*21I112	21 5/8	7 7/8	1 3/16	3/4	495	238	55	14.5
21WF73	21 1/4	8 1/4	3/4	1/2	338	148	54	9.5
21WF68	21 1/8	8 1/4	11/16	7/16	315	140	54	9
21WF62	21	8 1/4	5/8	3/8	284	130	53	8
20I85	20	7 1/8	15/16	11/16	337	195	51	11
*20I65	20	6 1/2	13/16	7/16	245	132	51	9
*20WF134	19 5/8	11 3/4	1 3/16	5/8	621	177	50	23.5
18WF60	18 1/4	7 1/2	11/16	11/16	243	115	46	9.5
*18I66	18 1/4	7	1	11/16	326	184	46	13
18WF55	18 1/8	7 1/2	5/8	3/8	220	108	46	8.5
*18I80	18	8	15/16	1/2	292	133	46	14
18WF50	18	7 1/2	9/16	3/8	200	99	46	8
18I55	18	6	11/16	1/2	199	126	46	7.5
*18WF122	17 3/4	11 3/4	1 1/16	9/16	648	145	45	23.5

Table 7-2. Properties of Steel Stringers (Con't)

NOMINAL SIZE	ACTUAL DEPTH (d) (in)	ACTUAL WIDTH (b) (in)	FLANGE THICKNESS ( $t_f$ ) (in)	WEB THICKNESS ( $t_w$ ) (in)	MOMENT CAPACITY $M$ (kips-ft)	MOMENT CAPACITY $V$ (kips)	MAX SPAN LENGTH ( $L_{max}$ ) (ft)	MAX BRACING SPACING ( $S_b$ ) (ft)
*18I62	17 3/4	6 7/8	3/4	3/8	238	100	45	9.5
*18I77	17 3/4	6 5/8	15/16	5/8	281	163	45	11.5
16WF112	16 3/4	11 3/4	1	9/16	450	136	42	23.5
*16I70	16 3/4	6 1/2	15/16	5/8	238	146	42	12
16WF50	16 1/4	7 1/8	5/8	3/8	181	94	41	9
16WF45	16 1/8	7	9/16	3/8	163	85	41	8
16WF64	16	8 1/2	11/16	7/16	234	106	40	12.5
16WF40	16	7	1/2	5/16	145	75	40	7.5
*16I50	16	6	11/16	7/16	155	105	40	8.5
16WF36	15 7/8	7	7/16	5/16	127	74	40	6.5
*16WF110	15 3/4	11 3/4	1	9/16	345	127	40	25
*16I62	15 3/4	6 1/8	7/8	9/16	200	129	40	11.5
*16I45	15 3/4	5 5/8	5/8	7/16	150	104	40	7.5
*15WF103	15	11 3/4	15/16	9/16	369	121	38	24.5
15I56	15	5 7/8	13/16	1/2	173	110	38	10.5
15I43	15	5 1/2	5/8	7/16	132	93	38	7.5
*14WF101	14 1/4	11 3/4	15/16	9/16	344	114	36	26
*14I40	14 1/4	5 3/8	3/8	3/8	119	83	36	8
*14I51	14 1/8	5 5/8	3/4	1/2	150	104	36	10
*14I70	14	8	15/16	7/16	204	87	35	18
*14I57	14	6	7/8	1/2	153	101	35	12.5
*14I40	14	5 1/2	5/8	3/8	121	78	35	8
14WF34	14	6 3/4	7/16	5/16	109	61	35	7.5
14WF30	13 7/8	6 3/4	3/8	1/4	94	58	35	6
*14WF92	13 3/8	11 3/4	7/8	1/2	297	96	34	25.5

Table 7-2. Properties of Steel Stringers (Con't)

NOMINAL SIZE	ACTUAL DEPTH (d) (in)	ACTUAL WIDTH (b) (in)	FLANGE THICKNESS (t <sub>f</sub> ) (in)	WEB THICKNESS (t <sub>w</sub> ) (in)	MOMENT CAPACITY m (kips-ft)	MOMENT CAPACITY v (kips)	MAX SPAN LENGTH (L <sub>m</sub> ) (ft)	MAX BRACING SPACING (S <sub>b</sub> ) (ft)
*14I46	13 3/8	5 3/8	11/16	1/2	126	99	34	9
*13I35	13	5	5/8	3/8	85	72	33	8
*13I41	12 5/8	5 1/8	11/16	9/16	108	104	32	9.5
*12WF36	12 1/4	6 5/8	9/16	5/16	103	56	31	9.5
*12I65	12	8	15/16	7/16	182	73	30	21
*12WF27	12	6 1/2	3/8	1/4	76	44	30	7
*12I50	12	5 1/2	11/16	11/16	113	120	30	10
*12I32	12	5	9/16	3/8	81	62	30	7.5
*12I34	11 1/4	4 3/4	5/8	7/16	81	72	28	8.5
*11WF76	11	11	13/16	1/2	202	77	28	27
*10I29	10 5/8	4 3/4	9/16	5/16	67	48	27	8.5
*10WF25	10 1/8	5 3/4	7/16	1/4	59	38	25	8
*10I40	10	6	11/16	3/8	92	53	25	14
*10I35	10	5	1/2	5/8	65	88	25	8
*10I25	10	4 5/8	1/2	5/16	55	46	25	7.5
*10WF21	9 7/8	5 3/4	5/16	1/4	48	36	25	6.5
*10WF59	9 1/4	9 1/2	11/16	7/16	132	56	23	23
*9I25	9 1/2	4 1/2	1/2	5/16	51	43	24	8
*9I50	9	7	13/16	3/8	103	45	23	21
*8I35	8	6	5/8	5/16	65	34	20	15.5
*8I28	8	5	9/16	5/16	49	35	20	11.5
*8WF31	8	8	7/16	5/16	61	33	20	14.5
*8WF44	7 7/8	7 7/8	5/8	3/8	81	40	20	21
*7WF35	7 1/8	7 1/8	9/16	3/8	58	37	18	18.5
*6WF31	6 1/4	6 1/4	9/16	3/8	45	31	16	18.5

\*THESE NOMINAL SIZES HAVE NO U.S. EQUIVALENT.

FOR STRINGERS NOT LISTED:

$$N_1 = \frac{S}{S_s} + 1$$

(Do not round off)

$$N_2 = \frac{3}{4} N_s$$

(Do not round off)

Use smaller of  $N_1$  or  $N_2$  for all further calculations.

- (4) Step 4: Determine the live load moment per lane,  $M_{LL}$ , from figure 7-3.

Calculate the live load moment per stringer,  $m_{LL}$ :

$$\text{Timber Stringer} : m_{LL} = \frac{M_{LL}}{N_1 \text{ or } N_2}$$

$$\text{Steel Stringer} : m_{LL} = \frac{1.15 (M_{LL})}{N_1 \text{ or } N_2}$$

- (5) Step 5: Determine the dead load moment,  $M_{DL}$ , for the entire span from figure 7-4.

Calculate the dead load moment per stringer ( $m_{DL}$ ):

$$m_{DL} = \frac{M_{DL}}{N_s}$$

- (6) Step 6: Calculate the total moment required ( $m_{REQD}$ ) per stringer:

$$m_{REQD} = m_{LL} + m_{DL}$$

Compare the total required moment ( $m_{REQD}$ ) with the moment capacity ( $m$ ) of the desired stringer found in table 7-1 or table 7-2.

(a) If the moment capacity ( $m$ ) is greater than the total required moment ( $m_{REQD}$ ), a moment failure will not occur. Proceed to Step 7.

(b) If the moment capacity ( $m$ ) is less than the total required moment ( $m_{REQD}$ ), add one stringer and return to Step 2 or select a stringer with a moment capacity greater than the required moment.

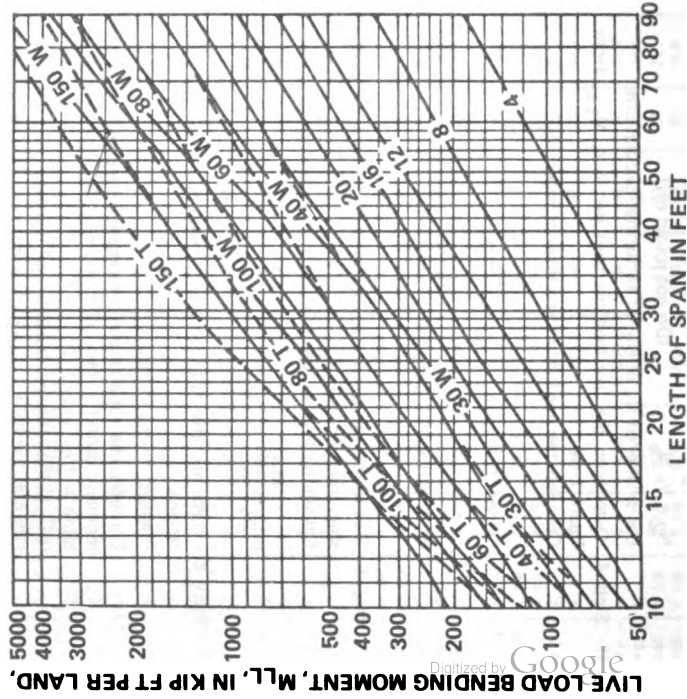


Figure 7-3 Live load moment graph.

L (FEET)	SPAN IN FEET	TIMBER STRINGER - TIMBER DECK ONE	TIMBER STRINGER - TIMBER DECK TWO	STEEL STRINGER - TIMBER DECK ONE	STEEL STRINGER - TIMBER DECK TWO	SPAN IN FEET
70						70
66						66
60						60
56						56
50						50
46						46
40						40
38						38
36						36
34						34
32						32
30						30
28						28
26						26
24						24
22						22
20						20
18						18
16						16
14						14
12						12
10						10
9						9
8						8

( $M_{DL}$  IS IN KIP- FEET;  
VOL IS IN KUPS)

Figure 7-4. Dead load moment and shear.

For an unlisted steel stringer:

$$m = 2.25 d_i (bt_f + \frac{d_i t_w}{6})$$

For an unlisted timber stringer:

$$m = \frac{b d^2}{30}$$

$d_i$  = depth of web

$t_w$  = thickness of web

$t_f$  = thickness of flange

$b$  = width of stringer

$d$  = depth of stringer

- (7) Step 7: Determine the live load shear per lane ( $V_{LL}$ ) from figure 7-5.

Calculate the live load shear per stringer ( $v_{LL}$ ):

$$\text{Timber Stringer : } v_{LL} = \frac{3V_{LL}}{16} \left[ \frac{N_1 \text{ or } N_2 + 1}{N_1 \text{ or } N_2} \right]$$

$$\text{Steel Stringer : } v_{LL} = \frac{1.15 V_{LL}}{2}$$

- (8) Step 8: Determine the dead load shear per span ( $V_{DL}$ ) from figure 7-4.

Calculate the dead load shear per stringer ( $v_{DL}$ ):

$$v_{DL} = \frac{V_{DL}}{N_s}$$

- (9) Step 9: Calculate the total shear required ( $v_{REQD}$ ) per stringer:

$$v_{REQD} = v_{LL} + v_{DL}$$

Compare the total required shear ( $v_{REQD}$ ) with the shear capacity ( $v$ ) of the desired stringer found in table 7-1 or table 7-2.

(a) If the shear capacity ( $v$ ) is greater than the total required shear ( $v_{REQD}$ ), a shear failure will not occur. Proceed to Step 10.

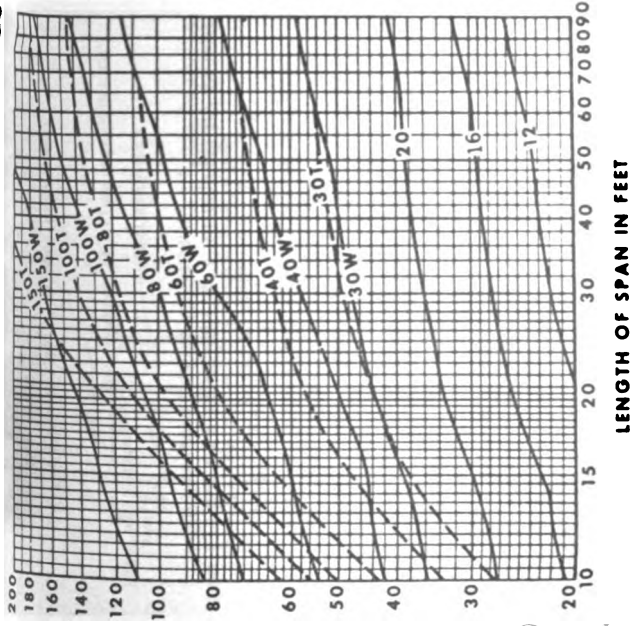


Figure 7-5. Live load shear graph.



For an unlisted steel stringer:

$$v = 16.5(d_f t_w)$$

For an unlisted timber stringer:

$$v = \frac{bd}{10}$$

Where:

d = depth of stringer

b = width of stringer

$t_w$  = thickness of web

(10) Step 10: Determine the number of lateral braces required between adjacent stringers:

Timber: Determine if braces are required from table 7-1. Minimum lateral bracing material is 3" by 1/2d of the stringer.

Steel: Lateral braces are always required with steel stringers. Space braces along span length evenly. Minimum bracing materials is 3/8" by 1/2d of stringer.

$$\text{number braces: } N_b = \frac{L}{S_b} + 1$$

(11) Step 11: Bearing plate design (fig. 7-6) required for all steel stringers (not required for timber).

$$L_{PL} = b_{cap}$$

$$B_{PL} = \frac{2(v_{REQD})}{L_{PL}} \quad (\text{Round up to nearest whole inch.})$$

NOTE: Minimum  $B_{PL}$  = stringer flange width

$$t_{PL} = \frac{B_{PL} - 2.5}{8.48} \quad (\text{Round up to nearest } 1/8'')$$

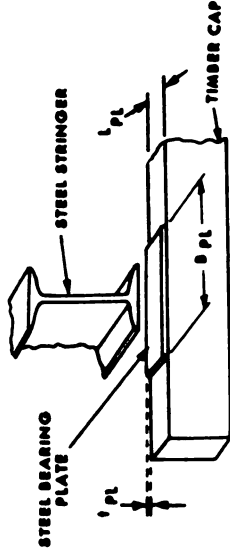


Figure 7-6. Bearing plate.

b. *Decking. Treadway, Curbing, and Handrail Design.*

Step 12: Determine the required decking thickness from the decking chart, figure 7-7, using the design class and the stringer spacing in inches. Add two inches to the required thickness if two or more layers of plank decking are required. (Two inches is added only ONCE regardless of number of layers stacked.) Absolute minimum decking thickness is 3 inches. For treadway, use at least 2-inch material. For curb and handrail design, see figure 7-8.

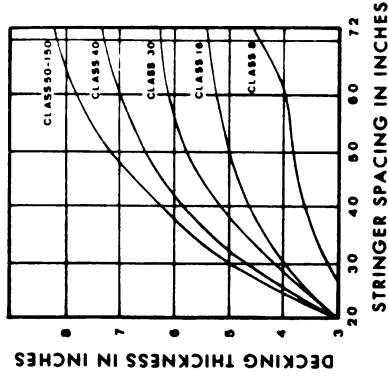
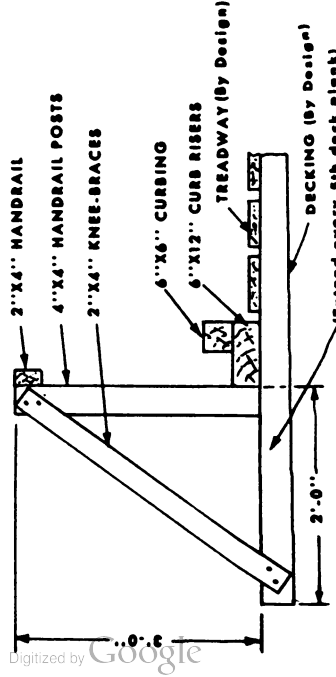


Figure 7-7. Decking chart.



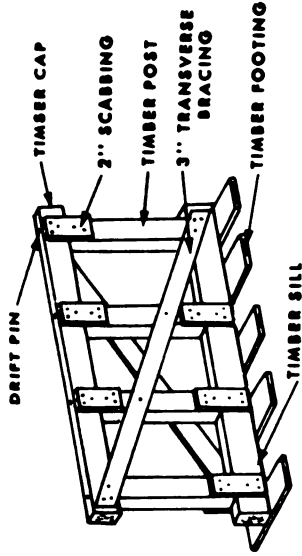


Figure 7-9. Timber trestle bent.

(1) Step 1: Determine critical support by finding the effective span length ( $L_e$ ) for each intermediate support:  
 $L_e = L_1 + L_2$  (sum of adjacent span lengths)

The support for which  $L_e$  is the greatest will be the critical support, which must be designed.

(2) Step 2: Check the post height ( $H$ ) of the tallest support against buckling. Post must be chosen from materials available (minimum post size is 6 in. x 6 in.) Find the maximum post height ( $H_m$ ) in table 7-3.

If  $H_m > H$ , buckling will not occur. Use horizontal braces at midpoint, or select a larger post if  $H_m \leq H$ .

NOTE: All bracing on intermediate supports should be bolted to posts, cap, and sill.

Table 7--3. Properties of Timber Posts

Size of Post (in)	Capacity per Post (kips)	Max. Height (ft)	Size of Pile (in)	Capacity Per Pile (kips)	Max. Height (ft)
6 x 6	18	15	8 $\phi$	25	18
6 x 8	24	15	9 $\phi$	32	20
8 x 8	32	20	10 $\phi$	40	22
8 x 10	40	20	11 $\phi$	47	25
10 x 10	50	25	12 $\phi$	56	27
10 x 12	60	25	13 $\phi$	66	29
12 x 12	72	30	14 $\phi$	76	31

(3) Step 3: Determine the design load acting on the critical support:

(a) Using the design class and  $L_e$ , determine the live load shear per lane ( $V_{LL}$ ) from figure 7-5.

(b) Using the adjacent span lengths,  $L_1$  and  $L_2$  separately, and the type of superstructure involved, determine the dead load shear ( $V_{DL}$ ) from figure 7-4.

(c) Using the number of lanes ( $N_L$ ), the live load shear per lane ( $V_{LL}$ ), and the dead load shear ( $V_{DL}$ ), compute the total design load,  $P_T$ :

$$P_T = V_{LL}(N_L) + V_{DL} \text{ (in kips)}$$

(4) Step 4: Determine the maximum load that one post can support, "capacity per post", from table 7-3.

(5) Step 5: Determine the number of posts required ( $N_p$ ) and the center-to-center post spacing ( $S_p$ ):

$$*N_p = \frac{P_T}{\text{capacity/post}}$$

\*(Note: For a pier use  $\frac{1}{2}P_T$ .)

Step 8: Check maximum allowable center-to-center spacing of posts:  
 $\max S_p = 5(d_{cap})$  (inches)  
 If  $\max S_p < S_p'$ , add posts until  $\max S_p \geq S_p'$  or use a cap with a larger  $d_{cap}$  dimension.

**NOTE:** Absolute minimum size cap and sill is 6 inches by 8 inches.

- (7) Step 7: Using the available footing material thickness in inches and the soil-bearing capacity of the soil on which the footing is to rest (table 7-4), determine the "K" value from figure 7-10. Then calculate the maximum allowable footing length,  $\max L_{ftg}$ :  
 $\max L_{ftg} = k + b_{sill}$  (inches)

Table 7-4. Soil Bearing Capacity

TYPE SOIL -- SBC (kips/sqft)	
Hardpan overlying rock	24
Very compact sandy gravel	20
Loose gravel and sandy gravel compact sand and gravelly sand, very compact sand in organic silt soils	12
Hard dry consolidated clay	10
Loose coarse to medium sand, medium compact fine sand	8
Compact sand clay	6
Loose fine sand, medium com- pact sand inorganic silt soils	4
Firm or stiff clay	3
Loose saturated sand--clay soils, medium soft clay	2

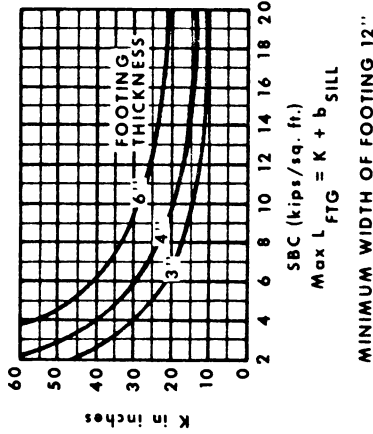


Figure 7-10. Footing chart.

- (8) Step 8: Using the soil-bearing capacity, (SBC in kips/sq ft) and the ground contact area of one footing (GCA in sq ft), compute the capacity of one footing.  
 Capacity/footing = (GCA)(SBC) (kips)
- (9) Step 9: Determine the number of footings required ( $N_{ftg}$ ) and the center-to-center footing spacing ( $S_{ftg}$ ):

$$* N_{ftg} = \frac{P_T}{\text{capacity/footing}}$$

NOTE: For a pier use  $\frac{1}{2}P_T$

$$S_{FTG} = \frac{W_R(12)}{(N_{FTG} - 1)} \quad (\text{inches})$$

6. **Timber Trestle Pier Design.** Design of a timber trestle pier is identical to the design of a timber trestle bent EXCEPT that each bent is designed for one-half the total load. Therefore, use  $\frac{1}{2}P_T$  in paragraph a, step 5, and step 9. A timber trestle pier, as shown in figure 7-11, will be used when loads are too great to be carried by a single bent or span lengths are greater than 25 feet. In addition to the nine design steps followed for the design of each bent, a common cap and corbel design must be made for a pier.

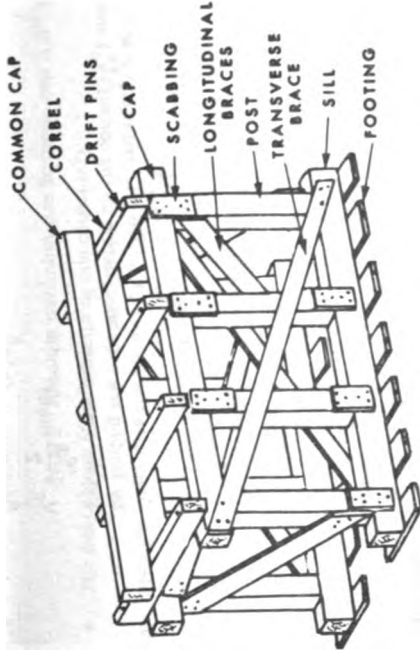


Figure 7 11. Timber trestle pier.

- (1) Step 1 through Step 9: For cap, sill, posts, and footing design for bents, see paragraph a.
- (2) Step 10: Determine the effective corbel length ( $L_C$ ):  
 $L_C$  = effective corbel length

NOTE: Minimum  $L_C = 1/6H_p$  or  $1/6 H$



- (3) Step 11: For design of corbels, check ratio of corbel length ( $L_c$ ) to depth of corbel ( $d_c$ ) to determine if moment or shear governs.

If  $\frac{L_c}{d_c} \leq 12$ , shear governs, proceed to step 13

If  $\frac{L_c}{d_c} > 12$ , moment governs, proceed to Step 12

- (4) Step 12: Determine the number of corbels ( $N_c$ ) required for moment by finding the total moment acting on the corbels ( $M_c$ ) and the moment capacity of one corbel ( $m_c$ ):

$$M_c = \frac{P_T(L_c)}{4} \quad (\text{ft-kips})$$

Determine  $m_c$  for one corbel from table 7-1.

$$N_c = \frac{M_c}{m_c} \quad \text{Proceed to Step 14}$$

- (5) Step 13: Determine the number of corbels ( $N_c$ ) required for shear by finding the total shear acting on the corbels ( $V_c$ ) and the shear capacity of one corbel ( $v_c$ ):

$$V_c = \frac{P_T}{2} \quad (\text{kips})$$

Determine  $v_c$  for one corbel from table 7-1.

$$N_c = \frac{V_c}{v_c}$$

- (6) Step 14: Determine the center-to-center spacing of the corbels based on the required number of corbels ( $N_c$ ) as determined in Steps 12 or 13:

cap  
(b<sub>cap</sub>) are minimum width of the common cap

$$\min d_{\text{cap}} = \frac{S_c}{5}$$

$$\min b_{\text{cap}} = \frac{2 P_T}{N_c b_c}$$

NOTE: Absolute minimum size common cap is 6" x 8".

c. *Pile Bent Design (fig. 7-12).*

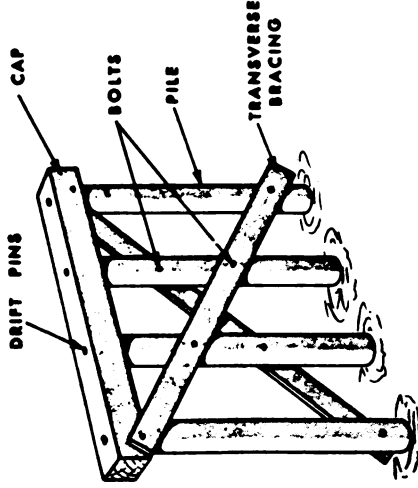


Figure 7-12. Pile bent.

NOTE: Pile type supports should be used instead of footing type supports when site conditions are affected by deep water or swift current causing scour, low capacity soil over-laying rock, or unconsolidated soil with low soil-bearing capacity.

- (1) Step 1 through Step 3: Determine total load ( $P_T$ ) on critical support (para a).
- (2) Step 4: Determine the capacity per pile ( $P_b$ ) based on end-bearing support from table 7-3.
- (3) Step 5: Determine the capacity per pile ( $P_f$ ) for friction support from one of the following dynamic formulas for timber piles (formulas based on test pile data or static formula — use lowest value)

$$\text{Drophammer} \quad P_f = \frac{2(W_d)(h)}{(S + 1.0)}$$

$$\text{Single-Acting} \quad P_f = \frac{2(W_d)(h)}{(S + 0.1)}$$

$$\text{Pneumatic or Diesel}$$

$$\text{Double-Acting} \quad P_f = \frac{2E}{(s + 0.1)}$$

$$\text{Pneumatic or Diesel}$$

$$\text{Static Formula} \quad P_f = \Sigma f(\pi D_p L_g)$$

$W_d$  = weight of drophammer (kips)

$h$  = average height of fall (ft)

$E$  = work energy of hammer (ft/kip)

$S$  = penetration of pile per blow for last 6 blows (inches/blow)

$f$  = friction coefficient from TM 5-312

$L_g$  = length of pile in soil layer

- (4) Step 6: Using the smaller of the two values obtained from Step 4 and Step 5 for the capacity per pile, determine the effective number of piles required ( $N_{pr}$ ):

$$N_{pr} = \frac{P_T}{P_b} \quad (\text{Do not round off})$$

will reduce the capacity of pressure bulbs which  
 $S_p = \frac{W_R(12)}{D_p} \sqrt{\frac{(N_{pr} - 1)D_p}{N_R}}$

NOTE: For a pile PIER, substitute  $\frac{N_{pr}}{2}$  for  $N_{pr}$ .

$$\text{If: } \frac{S_p}{D_p} > 10$$

Each pile develops full capacity.  
 Round  $N_{pr}$  off and continue to Step 9.

$$\frac{S_p}{D_p} < 3$$

Use a pile pier design.

$$3 \leq \frac{S_p}{D_p} \leq 10$$

Capacity is reduced due to pressure bulb overlap. Continue to Step 8.

- (6) Step 8: Determine the actual number of piles per row ( $N_p$ ) from the appropriate chart in figure 7-14, using  $N_{pr}$  obtained in Step 6 and  $S_p/D_p$  Ratio obtained in Step 7.

NOTE: Minimum  $N_p = 4$ .

- (7) Step 9: Calculate actual center-to-center spacing of piles and check spacing limitations.

$$\text{Actual } S_p = \frac{W_R \times 12}{(N_p - 1)} \quad (\text{inches})$$

$$\text{Minimum } S_p = 3(D_p) \quad (\text{inches})$$

$$\text{Maximum } S_p = 5(d_{cap}) \quad (\text{inches})$$

IF: Actual  $S_p < 3(D_p)$  Return to Step 7 and design a pile pier.

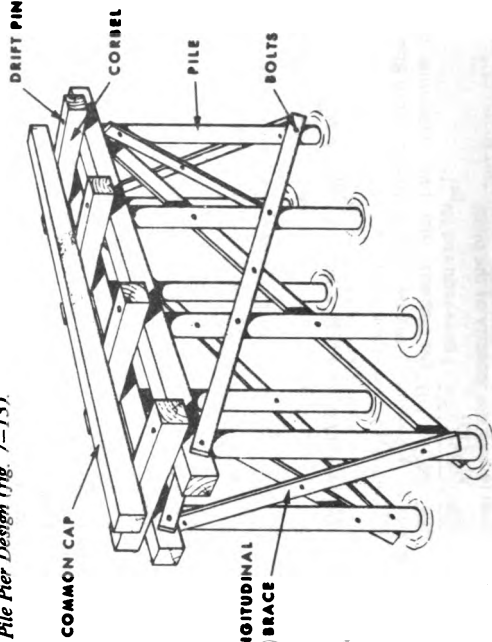
IF: Actual  $S_p > 5(d_{\text{caps}})$  Add more piles and check max and min spacing or increase depth of cap.  
 Calculate new  $S_p/D_p$  ratio based on  $N_p$ . Use appropriate pile chart to obtain  $N_{pe}$  using reverse procedure used for  $N_p$ .

$$\frac{S_p}{D_p} = \frac{W_r(12)}{(N_p - 1)D_p}$$

If  $N_{pe} \geq N_{pr}$  — OK

If  $N_{pe} < N_{pr}$  add 1 pile/row and repeat step 9 until  $N_{pe} \geq N_{pr}$

d. *Pile Pier Design (fig. 7-13).*



(1) Step 1 through Step 3:

Determine total load ( $P_T$ ) acting on the critical support (see para a).

(2) Step 4 through Step 9 (pile design based on spacing criteria): In Step 7 substitute  $\frac{1}{2}N_{pr}$  for  $N_{pr}$  and in Step 8 use the two-bent pile pier chart in figure 7-14 to determine the actual number of piles required per row (see para c).

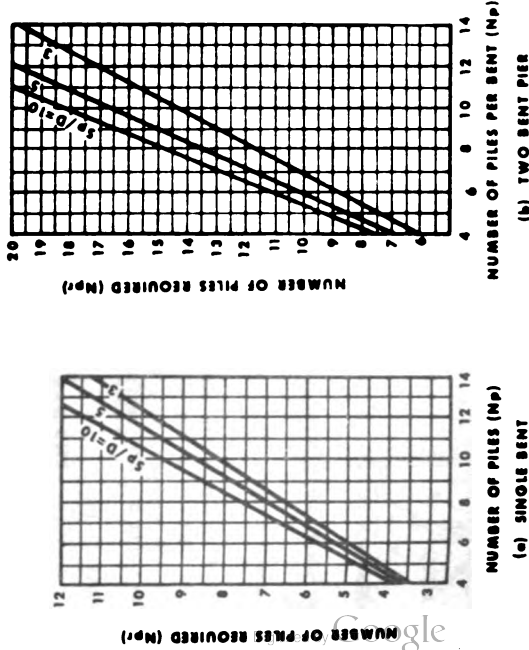


Figure 7-14. Pile charts.

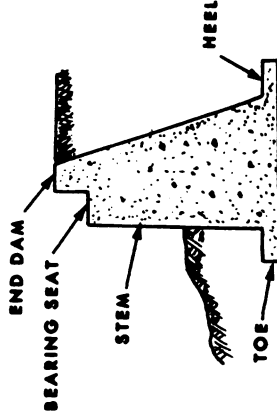
- (3) Step 10 through Step 15: Design common cap and corbel system (para b).

**NOTE:** Pile piers should be used in low capacity soils where pile bents do not give the required support or in situations requiring greater stability due to span lengths, support heights, or available material size.

## 1-5. SUBSTRUCTURE DESIGN

- a. See figures 7-15 through 7-18 and table 7-5 for selection of butments.
- b. *Deadman Design.* For deadman design, see TM 5-312.

**NOTE:** If time does not permit a detailed deadman design, use at least 4" diameter deadman at least as long as the roadway width. It should be attached to the abutment with at least ten  $\frac{3}{8}$ " diameter cables. The leadman should be buried 4' deep and placed 20' from the abutment.



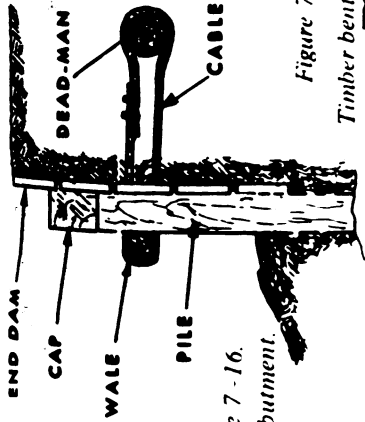
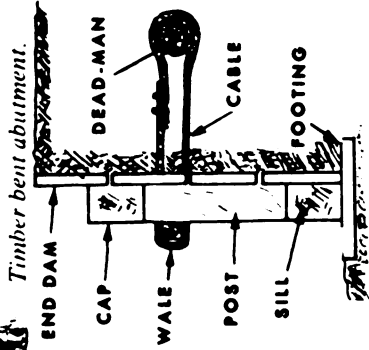


Figure 7-16.  
Pile abutment.

Figure 7-18.



Timber bent abutment.

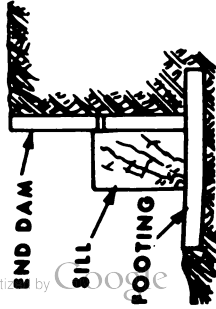


Figure 7-17.  
Timber sill abutment.



Table 7-5. Abutment Selection Guide

TYPE	HEIGHT	SITE CONDITIONS	DESIGN REMARKS
CONCRETE ABUTMENT	TO 20'	MOST PERMANENT TYPE. USE ON FIRM BANKS WITH GOOD SOIL.	FOR DESIGN, SEE TM 5- 312.
TIMBER SILL ABUTMENT	TO 3'	MOST ECONOMICAL AND EASILY CONSTRUCTED. USE ON HIGH, FIRM BANKS WITH GOOD SOIL.	DESIGN IS IDENTICAL TO TIMBER TRESTLE BENT WITHOUT POSTS. $L_e$ CONSISTS OF SUPPORTED SPAN ONLY (PAR a).
TIMBER BENT	TO 6'	USE ON FIRM BANKS WITH GOOD SOIL.	DESIGN IS IDENTICAL TO TIMBER TRESTLE BENT. $L_e$ CONSISTS OF SUPPORTED SPAN ONLY (PARA a). TO PREVENT OVERTURNING, USE DEADMAN.
PILE ABUTMENT	TO 10'	USE ON GENERALLY SLOPING BANKS WITH POOR SOIL CONDITIONS, WHEN STABILITY IS DESIRED, OR WHEN BANKS FLOOD FREQUENTLY.	DESIGN IS IDENTICAL TO PILE BENT. $L_e$ CONSISTS OF SUPPORTED SPAN ONLY (PARA c). TO PREVENT OVERTURNING, USE DEADMAN.

## 7-6. TIMBER TRESTLE BRIDGE CLASSIFICATION

Bridge classification is based on the class of the superstructure only, since this is considered to be the controlling feature. However, the condition of both superstructure and substructure components should be examined closely for damage or deterioration and the probable effect on the bridge capacity.

- (1) Step 1: Conduct a bridge reconnaissance to obtain the following information on the existing bridge:
  - Roadway width ( $W_R$ ) in feet
  - Span length ( $L$ ) in feet (critical span)
  - Type, size, and number of stringers
  - Type of decking and thickness of decking
  - Number of lateral braces
  - Condition of the components
- (2) Step 2: Locate the stringer to be classified in table 7-1 or table 7-2 and determine the moment capacity ( $m$ ) in ft-kips.
- (3) Step 3: Obtain the dead load moment per span ( $M_{DL}$ ) for the type superstructure involved from figure 7-4. (NOTE: If  $W_R \geq 18'$ , bridge is 2-lane.)
- (4) Step 4: Calculate the dead load moment per stringer ( $m_{DL}$ ) using the actual number of stringers ( $N_s$ ):

$$m_{DL} = \frac{M_{DL}}{N_s} \quad (\text{ft-kips})$$

- (5) Step 5: Calculate the live load moment per stringer ( $m_{LL}$ ) using the appropriate formula for either steel or timber stringers:

$$\text{Steel} : m_{LL} = \frac{m + m_{DL}}{1.15}$$

$$\text{Timber} : m_{LL} = m - m_{DL}$$

Check the maximum span length ( $L_m$ ) of the stringer from table 7-1 or table 7-2. If  $L_m > L$ , proceed to Step 6. If  $L_m < L$ , multiply  $m_{LL}$  by the ratio  $L_m/L$  to obtain a new and lower value of  $m_{LL}$ .

- (6) Step 6: Determine the effective number of stringers per lane for one-way traffic ( $N_1$ ) and for two-way traffic ( $N_2$ ). (If  $W_R \geq 18'$  by first computing the stringer spacing ( $S_s$ ):

$$S_s = \frac{W_R}{N_s - 1} \quad (\text{feet})$$

One-way traffic:  $N_1 = \frac{5}{S_s} + 1$

Two-way traffic:  $N_2 = \frac{3}{8} N_s$

(NOTE: DO NOT ROUND OFF  $N_1$  or  $N_2$ .)

For One-Way

If  $N_1 > N_2$  use  $N_1$

If  $N_2 > N_1$  use  $N_1$

For Two-Way

If  $N_1 > N_2$  use  $N_2$

If  $N_2 > N_1$  use  $N_1$

- (7) Step 7: Determine the live load moment per lane ( $M_{LL}$ ) using the value of  $m_{LL}$  obtained in Step 5 and  $N_1$  and/or  $N_2$  obtained in Step 6:

$$M_{LL} = N_1 (m_{LL}) \quad (\text{ft-kips/lane})$$

- (8) Step 8: Determine the classification of the bridge based on bending moment by entering figure 7-3 with  $M_{LL}$  and span length ( $L$ ) for both wheeled and tracked vehicles.

(NOTE: If  $N_1 > N_2$ , return to Step 7 and calculate  $M_{LL}$  using  $N_2$  in place of  $N_1$ . Another classification will be obtained from figure 7-3 which will give a class based on

(9) Step 9: Determine the shear capacity ( $v$ ) of the stringer in kips from table 7-1 or table 7-2.

(10) Step 10: Obtain the dead load shear per span ( $V_{DL}$ ) for the type superstructure involved from figure 7-4. Calculate the dead load shear per stringer ( $v_{DL}$ ):

$$v_{DL} = \frac{V_{DL}}{N_s} \quad (\text{kips per stringer})$$

(11) Step 11: Calculate the live load shear per stringer ( $v_{LL}$ ) using values for  $v$  and  $v_{DL}$  obtained in Step 9 and Step 10:

$$v_{DL} = v - v_{DL} \quad (\text{kips per stringer})$$

(12) Step 12: Determine the live load shear per lane ( $V_{LL}$ ) using the appropriate formula for either steel or timber stringers:

$$\text{Steel} : V_{LL} = \frac{2(v_{LL})}{1.15} \quad (\text{kips per lane})$$

$$\text{Timber} : V_{LL} = \frac{N_1}{3} (v_{LL}) \frac{N_1}{(N_1 + 1)}$$

(13) Step 13: Determine the classification of the bridge based on shear by entering figure 7-5 with  $V_{LL}$  and span length ( $L$ ) for both wheeled and tracked vehicles.

NOTE: If  $N_1 > N_2$ , return to Step 12 and calculate  $V_{LL}$  using  $N_2$  in place of  $N_1$ . Another classification will be obtained from figure 7-5 which will give a class based on two-way traffic.

(14) Step 14: Determine the maximum classification for both one-way and two-way traffic based on the roadway width restrictions ( $W_R$ ) (table 7-6).

Table 7-6. Minimum Roadway Width Requirements.

Bridge class	4-12	13-30	31-60	61-100
One-Lane	9'-0"	11'-0"	13'-2"	14'-9"
Two-Lane	18'-0"	18'-0"	24'-0"	27'-0"

- (15) Step 15: Determine the decking class by first calculating the effective thickness of decking ( $t_{eff}$ ) for the type of decking involved:

Laminated:  $t_{eff} = (t_{actual})(\% \text{ Lam})$

Plank:  $t_{eff} = t_{actual} - 2''$

(NOTE: Subtract 2" for *multilayered* plank deck only.)

Using the effective thickness ( $t_{eff}$ ) and the stringer spacing ( $S_s$ ) in inches, obtain the decking class from figure 7-7.

- (16) Step 16: Calculate the number of lateral braces required ( $N_b$ ) using the maximum spacing of bracing ( $S_b$ ) from table 7-2 for steel stringers:

Steel :  $N_b = \frac{L}{S_b} + 1$

Timber :  $N_b = 3$ , If  $d > 2b$  for stringer

If necessary, add bracing as required before posting final bridge classification sign.

- (17) Step 17: Determine the final bridge classification by comparing the classes for moment, shear, two-way width, and deck, and then selecting the lowest critical class for each type crossing, wheeled or track.

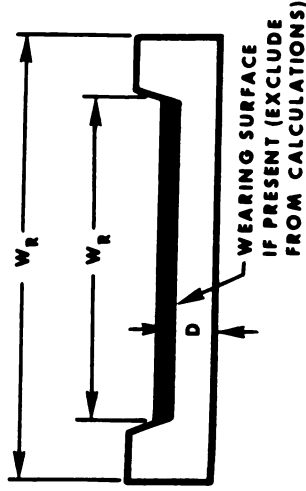
Type Crossing	TRACKED		WHEELED	
	One-Way	Two-Way	One-Way	Two-Way
MOMENT	Step 1	Step 8		
SHEAR	Step 9	Step 13		
WIDTH	Step 14			
DECK	Step 15			

**NOTE:** If the maximum one-way width determined in Step 14 is less than either of the final one-way classifications, a width restriction sign indicating the maximum width clearance must be posted below the bridge class sign.

## 7--7. REINFORCED CONCRETE BRIDGE CLASSIFICATION

Due to wide variations in design criteria, it is not possible to calculate the exact capacity of a reinforced concrete bridge based only on the measurable external dimensions. The class will be obtained by correlation to charts in TM 5-312.

Field measurements should be made on a concrete slab bridge as shown in Figure 7-19 and on a concrete T-beam bridge as shown in Figure 7-20, in order to classify the bridge according to TM 5-312.



*Figure 7-19. Concrete slab bridge.*

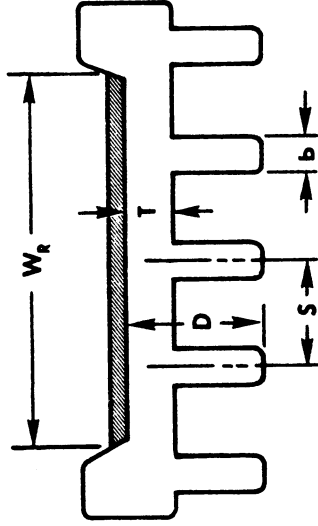
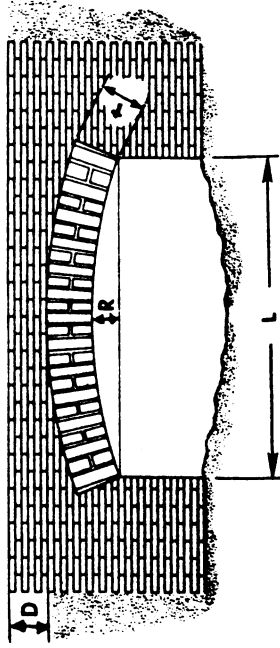


Figure 7-20. Concrete T-beam bridge.

## 7-8. MASONRY ARCH BRIDGE CLASSIFICATION

The masonry arch bridge is difficult to analyze for the purpose of obtaining a satisfactory military class. In order to classify a masonry arch bridge, make the necessary measurements as shown in figure 7-21 and follow the classification procedure as outlined and discussed in TM 5-312.



## 7-9. PANEL BRIDGE, BAILEY TYPE, M2, GENERAL INFORMATION

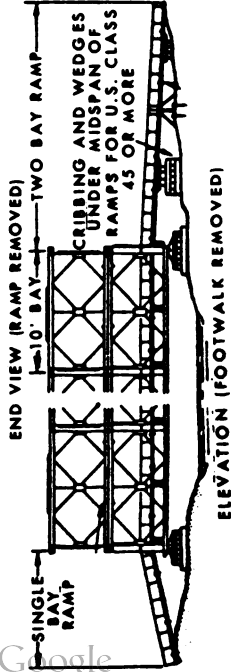
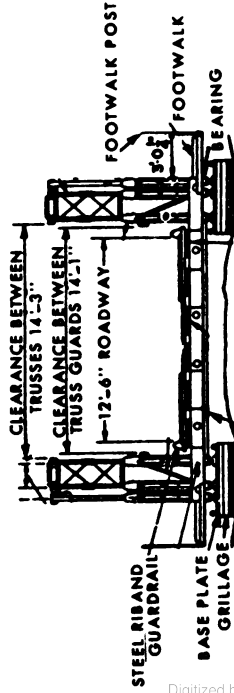
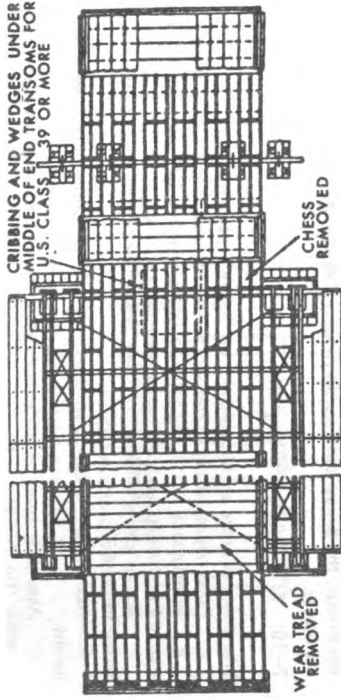
- a. The panel bridge, Bailey type, M2, is a through—truss bridge with the roadway supported between the two main trusses formed from 10—foot steel panels (fig. 7-22).
- b. The engineer panel bridge company is the TOE unit designated to carry one bridge set and provide technical personnel and equipment to transport and supervise the erection of panel bridging.
- c. The bridge set contains components required to erect two 80—foot DS bridges or one 130—foot DD bridge. See tables 7-7 and 7-8.
- d. The cable reinforcement set for panel bridge M2 (Bailey type) increases to class 60 wheel and track, the classification of triple—single Bailey bridge for span lengths from 100 feet to 170 feet. For a span of 180 feet, the class is 50 wheel and 60 track. This system significantly reduces the assembly time and equipment necessary to cross class 60 traffic over spans of between 100 and 180 feet.
- e. The cable reinforcement set consists of a system of cables attached to each end of the bridge and offset from under the bridge by posts. The cables are tensioned, causing the bridge to deflect upward. When a vehicle crosses the bridge, the bridge deflects downward, transferring part of the load into the cables.

## 7-10. SITE RECONNAISSANCE

Site reconnaissance should consider the following as a minimum:

- a. Road net on which to transport equipment to the assembly area.
- b. Approaches — a 150' straight approach, with a 10% slope or less, well graded and drained, and permitting two—lane traffic.
- c. Access roads — roads to and from the bridge capable of carrying traffic for which bridge is required.
- d. Abutments — check whether prepared or unprepared, assure equal height.
- e. Assembly areas — sufficient space for material stacking and bridge assembly (fig. 7-23).





Room width between steel ribs and  
Road width between timber truss girders  
Lateral *diverge* between centerlines of trusses

Upper trusses

Middle trusses

Outer trusses

Lateral distance *between* Centerlines of base plates

S truss bridge

D truss bridge

T truss bridge

Lateral distance between outside edges of base plates

S truss bridge

D truss bridge

T truss bridge

Lateral distance between measuring lugs of rocking roller templates

Lateral distance between measuring lugs of plain roller templates

SS, DS bridges

TS, DD, TD, DT, TT bridges

Longitudinal spacing between plain rollers

Height from base of base plate to top of chess

Height from base of rocking roller template to top of rocking roller

Height from base of plain roller template to top of plain roller

Height from base of ramp pedestal to top of ramp chess  
Height from bottom of half round lug under sloping end of ramp to top of ramp chess

Height from top of chess to overhead bracing

Normal

Expedient

Height from base of bearing to bottom of panel

Height from bottom of panel to top of chess

Height from bottom of half round lug of end post to top of chess

Height from base of rocking roller bearing to top of rocking roller

Room width between steel ribs and Road width between timber truss girders	12' 6" 13' 9"
Lateral <i>diverge</i> between centerlines of trusses	14' 10" 17' 10" 19' 3"
Upper trusses	14' 10" 16' 4"
Middle trusses	17' 3 1/2"
Outer trusses	19' 5" 20' 11"
Lateral distance between outside edges of base plates	21' 10 1/2"
S truss bridge	11' 6 1/2"
D truss bridge	
T truss bridge	
Lateral distance between measuring lugs of rocking roller templates	
Lateral distance between measuring lugs of plain roller templates	11' 6 1/2" 10' 10 1/2"
SS, DS bridges	25'
TS, DD, TD, DT, TT bridges	28 5/16" 16 5/16"
Longitudinal spacing between plain rollers	
Height from base of base plate to top of chess	
Height from base of rocking roller template to top of rocking roller	8 15/16"
Height from base of plain roller template to top of plain roller	17' 1/4" 5 7/8"
Height from base of ramp pedestal to top of ramp chess	
Height from bottom of half round lug under sloping end of ramp to top of ramp chess	
Height from top of chess to overhead bracing	14' 7" 12' 3"
Normal	5 17/32"
Expedient	20 11/16"
Height from base of bearing to bottom of panel	22 13/32"
Height from bottom of panel to top of chess	
Height from bottom of half round lug of end post to top of chess	13 5/16"
Height from base of rocking roller bearing to top of rocking roller	

Table 7-8. Weight per Bay of Bridge

CONSTRUCTION	WEIGHT PER BAY TONS
<b>BRIDGE</b>	
SS	2.76
DS	3.41
TS	4.01
DD	4.66
TD	5.88
DT	6.46
TT	8.29
<b>LAUNCHING NOSE</b>	
SS	1.00
DS	1.64
DD	2.90
<b>DECKING</b>	
Stringers only	0.79
Chess and steel ribands	0.66
<b>FOOTWALKS</b>	0.17
<b>OVERHEAD BRACING</b>	
Supports, transoms, away bracing, and chord bolts	0.54
<b>WEAR TREAD AND TRUSS GUARDS</b>	0.36

NOTE:

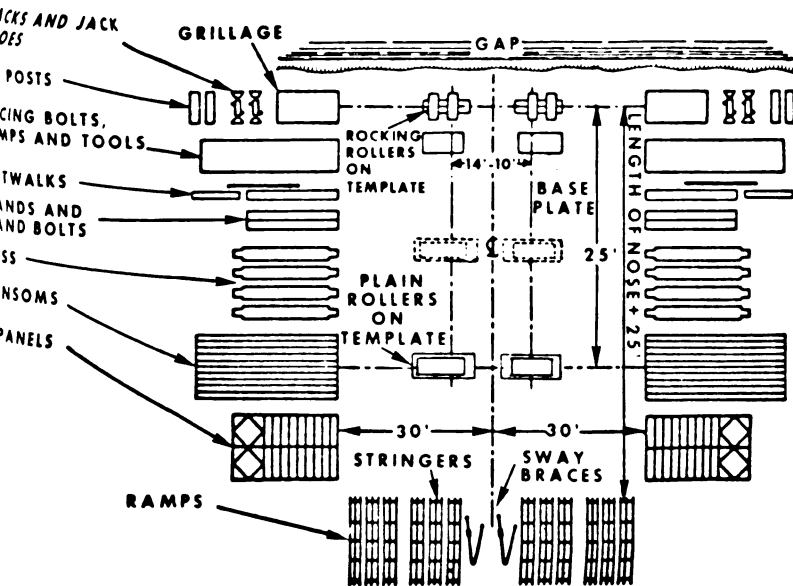


Figure 7-23. Suggested layout of equipment at bridge site.

- f. Turnaround — permit easy access to bridge assembly area.
- g. Equipment park — area large enough to hold all vehicles and close enough to allow proper control.

## 7-11. BAILEY BRIDGE DESIGN

Design of the Bailey bridge is beyond the scope of this publication and is outlined in detailed in TM 5-277.

## 7-12. PLANNING DATA

Tables 7-9 and 7-10 contain crew size and breakdown and estimated assembly times for standard bridges.

## 7-13. SITE LAYOUT DATA

Site layout data is beyond the scope of this publication. It is outlined in detail in TM 5-277.

## 7-14. ASSEMBLY AND LAUNCHING DATA

Assembly and launch procedures are beyond the scope of this publication and are outlined in TM 5-277.

## 7-15. MEDIUM GIRDER BRIDGE

Data on the medium girder bridge was not available at the time of publication. It will be incorporated into a change when available.

Table 7-9. Organization of Assembly Crews

	Type of Bridge						
	SS	DS	TS	DD	TD	DT*	TT*
Truck driver						0/1	0/1
Crane operator						0/1	0/1
Hook man						0/1	0/1
Panel carry	12	12	24	28	44	44/24	60/24
Pin	2	2	4	4	6	6/6	8/6
Transom-carry	8	8	8	8	8	24/16	24/16
Clamp	1	2	2	2	2	4/4	4/4
Brace, sway	2	2	2	2	2	6/6	6/6
Raker	2	2	2	2	2	2/2	2/2
Frame		2	2	4	4	8/10	8/8
Chord bolt				4	8	10/10	14/14
Tie plate			2		4		4/4
Overhead support						6/4	6/4
Decking-stringer	8	8	8	8	8	3/8	8/8
Chess & riband	4	4	4	4	4	4/4	4/4
.. Total	39	42	58	66	92	122/97	148/103

\*First number indicates men required without crane, second if crane is used.

\*\* All numbers reflect ideal number of men for each task.

Table 7-10. Assembly Times — Hours

Length	SS	DS	TS	DD	TD	DT (3)	TT (3)
40'	1½						
60'	1½	2					
80'	2	2½	3				
100'	2½	3	3½	4½			
120'		3½	4	5	6½		
140'		3½	4½	5½	7½	11½/10½	
160'			5	6½	8½	13½/11½	19/16½
180'				7	9½	14½/13½	21½/18½
200'						16½/14½	24/20½

(1) All times assume ideal conditions and footwalks omitted.

(a) Blackout - add 50 to 100 percent

(b) Bad weather - add 30 to 50 percent

(c) Untrained troops - add 20 to 30 percent

Example:  $(60' \text{ ss} = 1:45) + (\text{poor weather } (50\%) = 0:52) + (\text{untrained troops } (30\%) = 0:32) = 3:08$  (3 hours, 8 minutes)

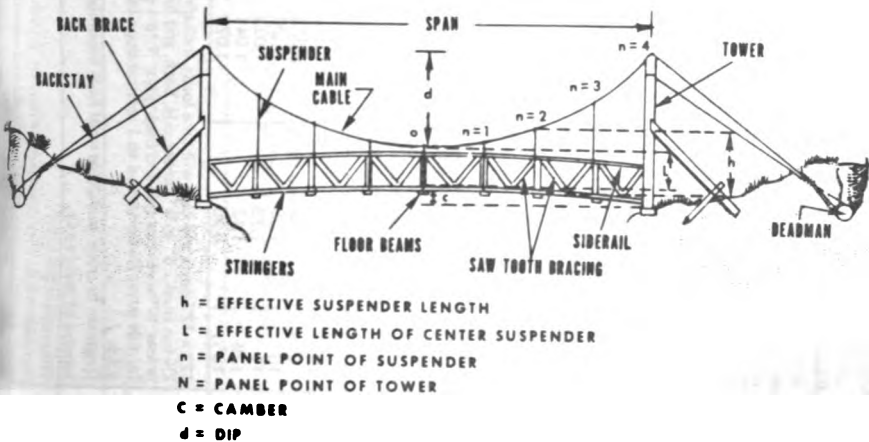
(2) Times do not include site preparation. Add 1 to 4 hours, depending on conditions.

(3) Second number refers to construction using a crane.

#### Section IV. MISCELLANEOUS BRIDGING

### 7-16. LIGHT SUSPENSION BRIDGE DESIGN

The suspension bridge (fig. 7-24) is used for long spans high above obstacles. The floor system is suspended from cables, which are supported on towers and anchored to abutments.



**Figure 7-24. Light suspension bridge.**



Table 7-11. Light Suspension Bridge Design Data

Item	Data
Panel length	10 to 15 ft.
Camber	Approximately 2 ft.
Stringer design	See paragraph 7-1a.
Floor beams	4" x 4" for foot troops or pack animals. 6" x 6" for ¼-ton truck. 8" x 8" for ¾-ton truck.
Stress in suspenders	Design for dead load of one panel, live load and 100% of live load for impact. See table 11-2 for cable strength.
Length of suspenders	$h = L + \left(\frac{n}{N}\right)^2 (C + d)$
Sag ratio	5% for foot bridges to 10% for animal and light vehicle bridges.
Main-cable design	Sag ratio %
	Max total tension in main cables, in parts of total suspended weight of bridge and load
	Length of cable between towers, in parts of span length
	7 1.94 1.012
	8 1.57 1.018
	9 1.46 1.022
	10 1.35 1.026
Towers	11 1.23 1.033
	12½ 1.12 1.041
	16²/₃ 0.90 1.070
	12" x 12" posts and caps will take loads, including a 2½-ton truck. 6" to 8" timber side, back, and fore-braces. ½" wire-rope side and back guys. 1 to 1 slope for side guys; 2½ horizontal to 1 vertical slope for back guys.
Anchorage	Deadman or other anchorage must hold maximum tension of main cable.
Factor of safety	Wire rope = 2 Cordage = 3.5

a 10 percent sag ratio and a 4 ton line load.

	<u>Pounds</u>
Suspended weight.....	
Line Load.....	20,000
Impact.....	8,000
	<hr/>
Total .....	36,000

Maximum total tension in main cables for a 10 percent sag ratio = 36,000 x 1.35 = 48,600 pounds. If two main cables are used, each must have a tensile strength of 24,300 pounds.

### 7-17. THREE ROPE BRIDGE (fig. 7-25)

The three-rope bridge is used to carry personnel with full field packs, but it is limited to a maximum of 7 men at 5 pace intervals. Maximum length is 150 feet. For construction details see TM 5-270.

### 7-18. FOUR-ROPE BRIDGE

The four-rope bridge is used to carry pack animals and personnel. Maximum length is 100 feet. Maximum capacity is 5 men with full field packs spaced 5 paces apart or one pack animal with handler. See TM 5-270.

### 7-19. ARMORED VEHICLE LAUNCHED BRIDGE (AVLB)

The AVLB is used to transport vehicles up to class 60. The bridge is 63 feet long and requires 3 feet of bearing on each side of the gap—an effective length of 57 feet. The AVLB may be launched or retrieved from either side of the gap and employed without exposing the operators to fire. It is found in armored Bns (2ea) and Div Engr Bns assigned to armored Divs (4 launchers and 6 bridges).



*Figure 7-25. Three-rope bridge.*

## 8-1. COMPONENTS OF CONCRETE

Concrete consists of a binder known as cement paste (portland cement and water) and filler material called aggregate (sand and gravel).

### a. Portland Cement Types.

(1) *Normal portland cement (Type I).* This is used for all general types of concrete construction, masonry units, and soil cement mixtures. Concrete made with Type I cement reaches its design strength after 28 days.

(2) *High-early portland cement (Type III).* This is used where high concrete strength is required after a short curing period. Concrete made with Type III cement reaches its design strength after 7 days. Type III is used where it is desired to remove forms as early as possible, to put concrete into service as early as possible, and in cold weather construction to reduce the period of protection against low temperatures.

(3) *Air-entrained portland cement (Types IA and IIIA).* Air-entrained cement increases the workability of plastic concrete and produces hardened concrete with greatly increased freeze-thaw resistance and watertightness. These air-entraining agents, which intentionally introduce minute air bubbles into the concrete mix, are recommended for all concrete construction. Air-entraining agents may also be added to the mix water at the job site.

*NOTE: Storage of cement.* As a minimum, cement bags should be stored on raised platforms with the top and sides protected by a waterproof covering.

### b. Mixing Water.

(1) The purpose of water in the concrete mix is to combine with the cement in the hydration process, coat the aggregate, and permit the mix to be worked.

(2) Mixing water should be clean and free from organic materials, alkalis, acids, and oil. In general, water that is fit to drink is suitable to mix with cement.

(3) Seawater may be used as mixing water with the understanding that the strength of the hardened concrete will be about 20 percent less than that mixed with fresh water.

c. *Sand.* The fine aggregate (sand) should be clean and free of salt, clay, or other materials which might coat the particles and impair binding of the cement paste.

d. *Gravel.*

(1) Coarse aggregate (gravel) should be hard, durable, and clean.

(2) The most economical concrete mix utilizes the largest gravel size possible. Physical restrictions of the concrete structure, however, restrict the maximum size gravel to the following:

(a) one-third the depth of the concrete slab on grade.

(b) one-fifth the thickness of the concrete wall.

(c) three-fourths of the minimum clear space between reinforcing steel or between reinforcing steel and the form.

## 8-2. CONCRETE MIX PROPORTIONING

a. *Mix Proportioning.* Mix proportioning is the selection of the most economical and practical combination of concrete components (cement, water, sand, and gravel) which will be workable in the plastic state and still develop the properties of strength, durability, and watertightness in the hardened state.

b. *Water-Cement Ratio.*

(1) The water-cement ratio is expressed in gallons of water per sack of cement. The water-cement ratio is of primary importance in mix proportioning in that the strength of the hardened concrete varies with this ratio. The lower the water-cement ratio, the higher the strength.

(2) Recommended water-cement ratios for concrete work follow:

(a) Use 6 gal/sack for an average mix

(b) Use 5 gal/sack for concrete placed under water, for concrete used in a watertight structure, when seawater is used for mix water, and when air-entraining is used.

(3) Adjust the water-cement ratio for moisture in the sand.

(a) Reduce  $\frac{1}{2}$  gal/sack for damp sand (when squeezed in your hand,

your fingers).  
c. Slump.

(1) Slump is a relative measure of:

- (a) Workability of a concrete mix — the ease of placement of the plastic concrete and its resistance to segregation.
- (b) Uniformity — a measure of similarity between batches made with the same mix proportions.

(2) Procedure for determining the slump of a concrete mix is:  
(a) Obtain or construct a slump cone as in figure 8-1.

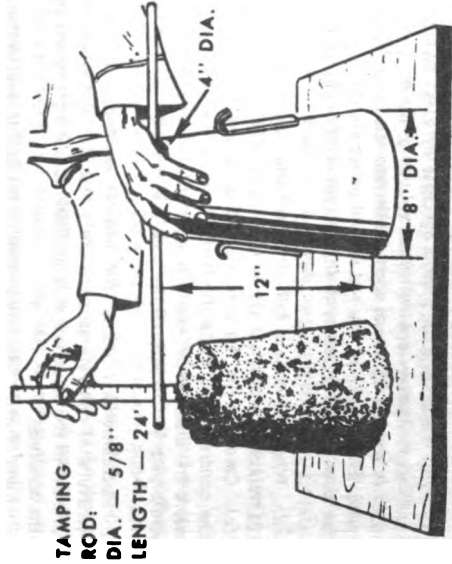


Figure 8-1. Measurement of slumps.

(b) Moisten the slump cone and place on a flat, level, moistened surface.

(c) Fill the cone with plastic concrete in three layers, each layer consisting of approximately one-third the volume of the cone. As each layer is placed, it is rodded 25 times with a 5/8-inch diameter, bullet-pointed tamping rod. Each stroke of the rod should penetrate the layer of concrete below the layer being tamped, with the bottom layer being tamped its entire depth.

(d) When the cone is full, strike off the excess concrete level with the top of the cone.

(e) Carefully lift the cone from the concrete and place the cone beside the concrete pile. Place the tamping rod across the top of the cone and measure the distance between the bottom of the rod and the center of the concrete pile. This measured distance that the concrete has fallen is the slump.

(3) Recommended slump for general concrete construction is 3 inches. Where thin concrete sections are to be cast and where reinforcing steel is present in the structure, it is advisable to use high-speed vibrators in placing the concrete.

d. *Sand and Gravel.* Recommended quantities of sand and gravel to be used for mix proportioning are listed in table 8-1.

Table 8-1. Concrete Mixes

MAXIMUM SIZE GRAVEL TO BE USED (INCHES)	AGGREGATE - CUBIC FEET PER 1 SACK OF CEMENT			
	SAND		GRAVEL	
	AIR-ENTRAINED	NON-AIR-ENTRAINED		
½ inches	1.9	2.0	1.5	
¾ inches	1.9	2.0	1.9	
1 inch	1.8	1.9	2.1	
1½ inches	1.8	1.9	2.5	
2 inches	1.8	1.9	2.7	

c. *Example Problem.* Select mix proportion for a concrete footer using air-entrained cement (Type IA).

- (1) Select w/c ratio (para 8-2b) — (w/c ratio = 6 gal/sack.)
- (2) Select slump (para 8-2c) — (slump = 3").
- (3) Select aggregate (table 8-1).

(a) Determine the moisture condition of the sand. (Sand is checked and found to be damp.)

(b) Determine the maximum size gravel to be used. (Maximum size aggregate available is  $\frac{3}{4}$ ".)

(c) Determine the type cement available. (air-entrained).

(d) Mix proportions for a one-sack batch are:

Water = 6 gal/sack minus  $\frac{1}{2}$  gal/sack =  $5\frac{1}{2}$  gal/sack

Cement = 1 sack air-entrained

Sand = 1.9 cu ft

Gravel = 1.9 cu ft

(e) Mix the one-sack batch selected in (d) above and make a slump test. If the slump measures less than 3 inches, mix a new one-sack batch using less sand and gravel. If the slump measures more than 3 inches, adjust the mix by adding sand and gravel to obtain the 3-inch slump. Never increase water content in an attempt to change a slump measurement. This practice changes the water-cement ratio, resulting in weakened concrete. When suitable proportions have been determined, convert the quantities of each material for the one-sack batch to those for a full mixer-size batch.

### 8-3. ESTIMATING AMOUNT OF MATERIALS REQUIRED

a. *Amounts of Materials.* The amounts of cement, water, sand, and gravel to be ordered and delivered to the job site may be estimated according to the following steps:

- (1) Determine the volume of concrete needed in cubic feet.
- (2) Add a loss factor to compensate for handling losses. Add 10% for projects requiring up to 200 cubic yards (5400 cubic feet) of concrete and 5% for projects requiring 200 cubic yards or more.
- (3) Determine the total volume of loose, dry material (total cement, sand, and gravel) required. Multiply the volume of concrete (plus the loss factor) times 1.5.



- (4) For estimating purposes, assume mix proportions of 1 part cement, 2 parts sand, and 3 parts gravel ( $1:2:3 = 6$ ). Determine amounts of each material by multiplying the total loose volume (Step 3) by the proportional amount of the total mix:

$$\text{cement} = 1/6 \times \text{total loose volume}$$

$$\text{sand} = 2/6 \times \text{total loose volume}$$

$$\text{gravel} = 3/6 \times \text{total loose volume}$$

- (5) The amount of water needed may be determined by using a rule of thumb of 8 gallons of water per sack of cement. This amount will allow for mixing water as well as water used in curing and cleanup.

*b. Example Problem.* Determine the amounts of materials needed to construct a concrete wall measuring 10 feet long, 3 feet high, and 1 foot thick.

- (1) Volume of concrete =  $10 \text{ ft} \times 3 \text{ ft} \times 1 \text{ ft} = 30 \text{ cu ft}$ .
- (2) Add 10% loss factor (less than 200 cu yd).  
 $30 \text{ cu ft} + 3 \text{ cu ft} = 33 \text{ cu ft}$
- (3) Volume of loose, dry materials =  $33 \text{ cu ft} \times 1.5 = 49.5 = 50 \text{ cu ft}$ .
- (4) Amount of each material required:
  - Cement =  $50 \text{ cu ft} \times 1/6 = 8.3 = 9 \text{ cu ft (bags)}$
  - Sand =  $50 \text{ cu ft} \times 2/6 = 16.7 = 17 \text{ cu ft}$
  - Gravel =  $50 \text{ cu ft} \times 3/6 = 25 \text{ cu ft}$
- (5) Water =  $8 \text{ gal/bag} \times 9 \text{ bags} = 72 \text{ gal}$

#### 8-4. ESTIMATING QUANTITY OF STORED AGGREGATE (fig. 8-2)

Aggregate is often stored in cone-shaped or tent-shaped piles. A good formula to estimate the volume of aggregate in a cone-shaped pile is:  $\text{volume} = 0.2618 \times \text{height} \times \text{cone diameter squared}$ . The volume of a tent-shaped pile is:  $\text{volume} = 0.2618 \times (\text{height} \times \text{cone diameter squared}) + .5 \times \text{height} \times \text{length of the linear section}$ . The weight of the stored aggregate is determined by multiplying the volume by the unit weight of

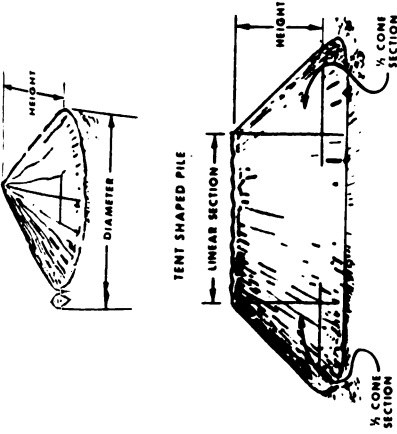


Figure 8-2. Estimating quantity of stored aggregate.

## 8-5. BATCHING

- a. Once a design mix has been determined, lay out the site, placing the cement, sand, gravel, and water as close to the skip (load bucket) of the mixer as possible.
- b. The gravel should be placed in the skip first, the cement next, and the sand last. The exact amount can be controlled by constructing measuring boxes which have inside dimensions of 1 cubic foot and then measuring all sand and gravel as it is placed in the skip. Water can be placed into the mixer either by the use of a metering device on the mixer or by hand.

The actual mixing time will depend on the method of discharge and size of batch. If discharge is directly into the form, the mixing time should be at least 1 minute for any mix. For a batch exceeding 1 cubic yard, the mixing time is increased 15 seconds for each additional  $\frac{1}{2}$  yard or portion thereof.

## 8-6. CONCRETE PLACING AND FINISHING

- a. Moisten the grade to prevent absorption of water from the mix.
- b. Oil all forms before placing concrete.
- c. Wheel, shovel, or chute concrete into place—do not flow. Concrete should not be allowed to free fall into forms from heights greater than 5 feet unless suitable drop chutes, baffles, or vertical pipes are provided. As concrete is placed, it should be compacted by vibrators, spades, or rods. Take care not to overvibrate.
- d. Level and tamp into place with a strike-off screed.
- e. Delay wood floating for 30 to 40 minutes after the concrete is placed.
- f. Apply final steel troweling when thumb pressure barely dents the concrete surface. Final troweling compacts the surface and leaves it smooth.
- g. Start curing as soon as possible without marring the surface.

## 8-7. CURING

- a. Curing is the procedure for preventing the evaporation of mixing water from the surface of freshly poured concrete. Loss of water from the concrete will terminate, or at least limit, the chemical reaction (hydration) of cement and water. Since concrete will gain strength only so long as water is available to react with the cement, evaporation of this water will reduce the actual strength below designed strength.
- b. To obtain the designed strength, concrete made with Type I cement must be cured (kept continuously wet) a minimum of 7 days. Concrete made with Type III cement must be cured a minimum of 3 days.
- c. Methods used to properly cure concrete depend upon the type of structure and may be accomplished by spraying or ponding, by covering with continually moistened earth, sand, burlap, or straw, or by covering with a water-retaining membrane.
- d. If spray-on curing compound is available, spray on the compound in one coat. Do not use the compound if the air temperature is above 100°F and the air is dry.

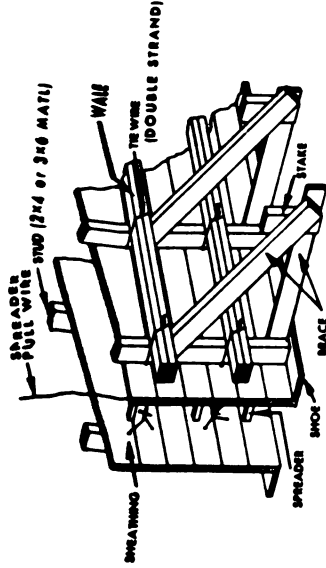


Figure 8-3. Form for a concrete wall.

(1) *Sheathing.* Sheathing forms the surfaces of the concrete. It should be as smooth as possible, especially if the finished surfaces are to be exposed. Since the concrete is in a plastic state when placed in the form, the sheathing should be watertight. Tongue and groove sheathing gives a smooth watertight surface. Plywood or masonite can also be used.

(2) *Studs.* The weight of the unhardened concrete will cause the sheathing to bulge if it is not reinforced. Studs are run vertically to add rigidity to the wall form. Studs are generally made from 2 x 4 lumber.

(3) *Wales.* Studs also require reinforcing when they extend over 4 or 5 feet. This reinforcing is supplied by double wales. Double wales also serve to tie prefabricated panels together and keep them in a straight line. They run horizontally and are lapped at the corners of the forms to add rigidity. Joints normally should be staggered to minimize weaknesses in form construction. Wales usually are made of the same material as the studs.

(4) *Braces.* Bracing is usually required to maintain the vertical alignment of the forms and to resist movement during the concrete-pouring operation. Bracing is not considered a structural component in wall form design; i.e., it does not support the pressure of unhardened concrete.

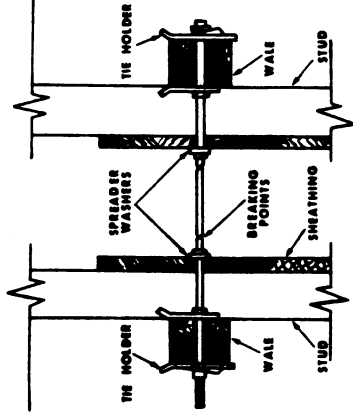


Figure 8-4. Form for a concrete wall.

(5) *Shoe plates.* The shoe plate is nailed into the foundation or footing and is carefully placed to maintain the correct wall dimension and alignment. The studs are nailed to the shoe and spaced according to the wall form design.

(6) *Spreaders.* To maintain the proper distance between the two form sides, small pieces of wood (spreaders) are cut the same length as the wall thickness and placed between the forms. A wire should be securely attached to the spreaders so they can be pulled out from the top after the concrete has exerted its total pressure on the walls. The spreaders must be removed before the concrete hardens.

(7) *Form ties (wire or tie rods).* Ties resist the outward pressure on unhardened concrete. Where wire ties are used, a double strand is necessary.

(8) *End walls (dams).* Dams must provide the same strength as the sides of the wall form. Examples of end wall forming appear as figure 8-5. Note that wall thickness dictates the choice of end wall detail.

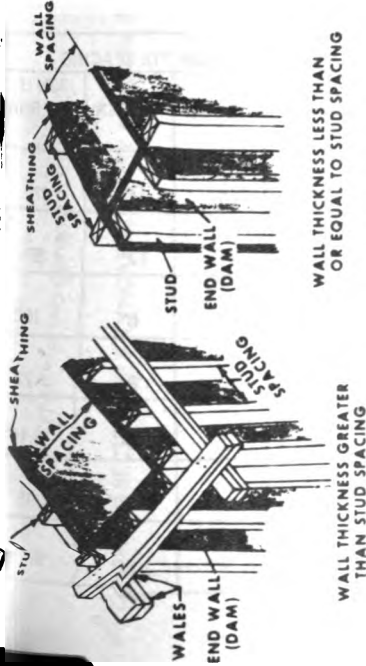


Figure 8-5. Recommended end wall (dam) details.

b. *Wall Form Design.* When more detailed form design methods are unavailable and 2 x 4 framing lumber is to be utilized (single 2 x 4 studs and double 2 x 4 wales), table 8-2 may be used as follows:

- (1) Determine the rate of pour in feet per hour (the height of concrete being placed into the form per hour).
- (2) Select the sheathing material to be used.
- (3) Read the center--to--center stud spacing in inches.
- (4) Read the center--to--center wale spacing in inches.
- (5) Select the column for the tie material to be used (8, 9, or 10 gage wire or 3000-lb manufactured tie rods). Read, in inches, the maximum spacing of ties to be placed at each wale.

Table 8-2. Wall Form Design

MAXIMUM RATE OF POUR (FT/HR)	SHEATH MATERIAL	STUD SPACING	DOUBLE WALE SPACING	MAXIMUM TIE SPACING			
				8 GA	9 GA	10 GA	3000 LB TIE RODS
4'	5/8" Plywood	8"	24"	17"	14"	11"	27"
	1" Board	16"	16"	25"	21"	17"	29"
8'	5/8" Plywood	6"	24"	8"	7"	6"	15"
	1" Board	12"	16"	12"	10"	9"	22"
12'	3/4" Plywood	6"	16"	8"	7"	6"	15"
	1" Board	8"	16"	8"	7"	6"	15"
	2" Board	16"	12"	11"	9"	8"	20"

9-1. CROSS-SECTION OF A TYPICAL MILITARY ROAD (fig. 9-1)

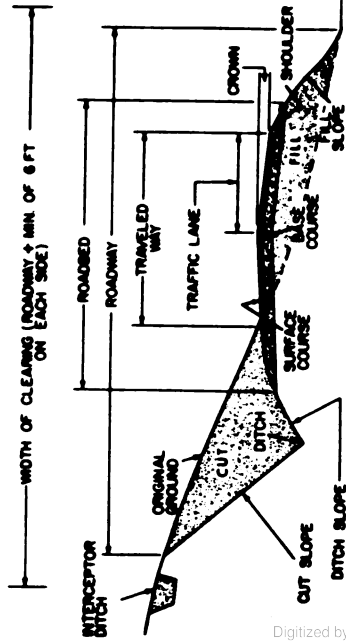


Figure 9-1. Typical cross section illustrating road nomenclature.



## 9-2. MINIMUM DESIGN REQUIREMENTS (table 9-1)

Table 9-1. Military Road Specifications

Characteristics	Specification
Width: Traveled way (single lane) Traveled way (two lanes) Shoulders (each side) Clearing	Min 11 5 ft (3.5 meters) Min 23 ft (7.0 meters) Min 4 ft (1.5 meters) Min 6 ft (2 meters) on each side of roadway
Grades: Absolute maximum Desirable maximum	Lowest maximum gradability of vehicles for which road is built Tangents and gentle curves, less than 6%. sharp curves, less than 4%
Horizontal curve radius Vertical curve length: Invert curves Overt curves	Desired min - 150 ft (45 meters) 100 ft min (30 meters) for each 4% algebraic difference in grades 125 ft min (40 meters) for each 4% algebraic difference in grades
Sight distance: Nonpassing Passing	Absolute minimum - 200 ft (60 meters) Absolute minimum - 600 ft (180 meters)
Load capacity: Road proper Bridges	Sustain 18,000-lb single axle, dual wheel equivalent load Accommodate using traffic
Slopes: Shoulders Crown (gravel and dirt) Crown (paved) Superelevation Cut Fill	$\frac{3}{4}$ to $1\frac{1}{2}$ in per ft $\frac{1}{2}$ to $\frac{3}{4}$ in per ft $\frac{1}{4}$ to $\frac{1}{2}$ in per ft $\frac{1}{2}$ to $1\frac{1}{4}$ in per ft Variable } (Determined by soil types) Variable } (versus compaction)
Drainage	Adequate crown or superelevation with adequate ditches and culverts in good condition. Take full advantage of natural drainage. Try to locate road at least 5 ft above the ground water table.
Miscellaneous: Overhead clearance Traffic volume	Min - 14 ft (4.3 meters) 2,000 vehicles per day

## 9-4. SOILS

- Soils Pertinent to Roads and Airfields (table 9-2).
- Procedure for Field Identification Tests of Soils (fig. 9-3).

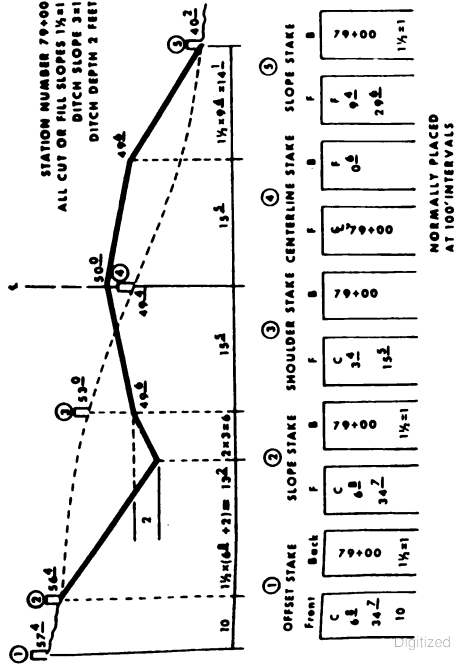


Figure 9-2. Diagram of construction stake placement and marking.

Table 9-2. Soil Characteristics

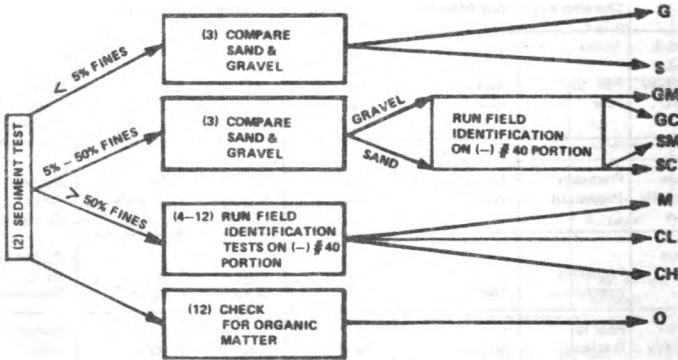
Symbol	Description	Drainage Characteristics	Airfield Index (Frost Susceptibility)	Value as A Subgrade	Value as A Subbase	Value as A Base	Compaction Equipment
G	Gravels and Sandy Gravel with little or no Fines	Excellent	None to very Slight	Good to Excellent	Good to Excellent	Fair to Good	Crawler Tractor, Rubber Tire Roller, Steel Wheel Roller
GM	Silty Gravels, Gravel-Sand-Silt Mixture	Fair to Practically Impervious	Slight to Medium	Good	Fair to Good	Not Suitable	Rubber Tire Roller, Sheepfoot Roller
GC	Clayey Gravels, Gravel, Sand-Clay Mixtures	Poor to Practically Impervious	Slight to Medium	Good	Fair	Not Suitable	Rubber Tire Roller, Sheepfoot Roller
S	Sands and Gravels, Sands with little or no Fines	Excellent	None to very Slight	Fair to Good	Fair to Good	Poor to not Suitable	Crawler Tractor, Rubber Tire Roller
SM	Silty-Sands, Sand-Silt Mixtures	Fair to Practically Impervious	Slight to Medium	Fair to Good	Poor to Fair	Not Suitable	Rubber Tire Roller, Sheepfoot Roller
SC	Clayey Sands, Sand-Clay Mixtures	Poor to Practically Impervious	Slight to High	Poor to Fair	Poor	Not Suitable	Rubber Tire Roller, Sheepfoot Roller

Table 9-2. Soil Characteristics (Continued)

Description	Drainage Characteristics	Airfield Index (Frost Susceptibility)	Value as A Subgrade	Value as A Subbase	Value as A Base	Compaction Equipment
Inorganic silts & very fine sand rock flour, clayey silts with slight plasticity	Fair to Poor	Medium to High	Poor to Fair	Not Suitable	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
Inorganic clays low to medium Plasticity, gravelly or sandy clays	Practically Impervious	Medium to High	Poor to Fair	Not Suitable	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
Inorganic clays of high plasticity	Practically Impervious	Medium	Poor to Fair	Not Suitable	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
Mineral grains containing highly organic matter	Poor to Practically Impervious	Medium to High	Poor to Very Poor	Not Suitable	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
Peat and other highly decomposed vegetable matter	Fair To Poor	Slight	Not Suitable	Not Suitable	Not Suitable	Compaction not Practical

## SAMPLE

## (1) SEPARATE GRAVEL



**NOTE: THIS PROCEDURE WILL GIVE A VERY HASTY CLASSIFICATION OF SOILS, AND SHOULD NOT BE USED FOR DESIGN OF PERMANENT OR SEMIPERMANENT CONSTRUCTION.**

(No. 4 sieve).

Remove from the sample all particles larger than  $\frac{1}{8}$ " diameter

(b) Estimate the percent of gravel.

(2) *Sedimentation test to determine % sand. (This test eliminates fines.)*

### METHOD ONE

(a) Place the sample (less gravel) in canteen cup and mark the level with a grease pencil.

(b) Fill with water and shake the mixture vigorously.

(c) Allow the mixture to stand for 30 seconds to settle out.

(d) Pour off the water.

(e) Repeat steps (b) through (d) until the water poured off is clear.

(f) Dry the soil left in the cup (sand).

(g) Estimate % sand by comparing the new level of sand with the mark. % sand = total beginning volume of sample minus % gravel eliminated in paragraph (1) (b) above minus fines eliminated in (2) (a) thru (2) (f) above.

OR

### METHOD TWO

(a) Put approximately 1" of the sample in a glass jar.

(b) Mark the depth of the sample with a grease pencil.

(c) Fill the jar with 5 to 6 inches of clear water. Leave 1" of air at the top.

(d) Shake the mixture vigorously (3 to 4 minutes).

(e) Allow the sample to settle for 30 seconds.

(f) Compare the sediment line with the grease pencil mark.

(g) Estimate % sand settling to the bottom of the jar (by volume, compare the sediment line with the grease pencil mark). % sand = total beginning volume of sample minus % gravel eliminated in (1) (b) above minus fines eliminated in (2) (a) thru (2) (f) above.

### (3) *Comparison of gravel, sand, and fines.*

- (a) Percent of gravel was estimated in paragraph (1) (b) above.
- (b) Percent of sand was estimated in paragraph (2) (g) above by either of two methods.
- (c) Percent of fines = 100 minus % gravel minus % sand.

### (4) *Dry strength.*

- (a) Form a moist pat 2" in diameter by  $\frac{1}{2}$ " thick.
- (b) Allow to dry with low heat.
- (c) Place the dry pat between thumb and index finger only and attempt to break.

(d) If the pat breaks easily, it is silt (M). If the pat is difficult to break, it is low compressible clay, (CL). If breakage is impossible, it is high compressible clay (CH).

### (5) *Powder Test.*

- (a) Rub a portion of the broken pat with the thumb and attempt to flake particles off.
- (b) If the pat powders, it is silt (M). If the pat does not powder, it is clay (C).

### (6) *Feel Test.*

- (a) Rub a portion of dry soil over a sensitive portion of the skin, such as the inside of the wrist.
- (b) If the feel is harsh and irritating, sample is silt (M).
- (c) If the feel is smooth and floury, sample is clay (C).

### (7) *Shine test.*

- (a) Draw a smooth surface, such as a knife blade or thumb nail, over a pat of slightly moist soil.

(b) If the surface becomes shiny and lighter in texture, the sample is a high compressible clay (CH). If the surface remains dull, the sample is a low compressible clay (CL). If the surface is very dull or granular, the sample is silt (M) or sand (S).

### (8) *Thread test.*

- (a) Form a ball of moist soil (marble size).
- (b) Attempt to roll the ball into a  $\frac{1}{8}$ " diameter thread (wooden match size).

... if a thread is easily obtained, the ball is clay (C). If a thread

(b) *Roll* a cylinder of moist soil approximately cigar shape in size, try to form ribbon 8 to 9 inches long, 1/8 to 1/4 inch thick, and 1 inch wide.  
(c) If an 8 to 9 inch ribbon is obtained the sample is high compressible clay (CH). If the ribbon is less than 8 inches, it is low compressible clay (CL). If no ribbon can be obtained, the sample is silt (M) or sand (S).

(10) *Grit, or bite test.*

- (a) Place a pinch of the sample between the teeth and bite.
- (b) If the sample feels gritty, it is silt (M). If the sample feels floury, it is clay (C).

(11) *Wet shaking test.*

- (a) Place a pat of very moist (not sticky) soil in the palm of the hand.

(b) Shake the hand vigorously and strike against the other hand.

(c) Observe the rapidity of the water rising to the surface. If fast, the sample is silty (M). If there is no reaction, sample is clayey (C).

(12) *Odor test.*

(a) Heat the sample with a match or open flame.

(b) If the odor becomes musty or foul smelling, this is a strong indication that organic material is present.

c. *Determination of Optimum Moisture Content (OMC).* To determine whether or not a soil is at or near OMC, mold a golf ball size sample of the soil with your hands. Then squeeze the ball between your thumb and fore fingers. If the ball shatters into several fragments of rather uniform size, the soil is near or at OMC. If the ball flattens out without breaking, the soil is wetter than OMC. If, on the other hand, the soil is difficult to roll into a ball or crumbles under very little pressure, the soil is drier than OMC.

## 9-5. DRAINAGE

a. *Ditches.*

- (1) A triangular "Vee" ditch is normally used for relatively small volumes of water. It is easily cut with the motorized grader.



(2) A trapezoidal ditch should be used where:

- (a) Large quantities of water are expected to be handled.
- (b) Fine-grained soils are present, and high water velocities (over 3 to 4 fps) will cause excessive erosion.

(3) Minimum longitudinal slope for ditches is 0.5%, 2% preferred, and 4% is the maximum allowable without erosion controls. In fine-grained soils, erosion controls may be required in ditch slopes much less than 4%.

(4) In the absence of more detailed design, a good roadside ditch is a 2--foot-deep triangular ditch having slopes of 3:1 on the side adjacent to the roadway and 1:1 on the outside.

b. *Check dams.* Check dams are used to slow the water and prevent erosion in ditches that have longitudinal grades of 2% to 8%. They may be made of timber, sandbags, concrete, rock, or similar materials. Figure 9--4 shows the method of computing check dam spacing.

### (c) Culverts.

(1) *General.* Culverts are required wherever drainage channels are needed to cross roads, to provide ditch relief, and to continue side ditches at the intersections of roads and access routes.

(2) *Cross-sectional area.*

(a) *By field estimate method.* (Use for an area of  $\leq 100$  acres that does not have a stream flowing through it.)

$$Q = 2 \text{ ARC}$$

Q = The volume of water in cubic feet per second

2 = A constant

A = The area of the drainage basin in acres

R = The design rainfall intensity based on the 1-hour, 2-year frequency rainstorm

C = The ratio of runoff to rainfall

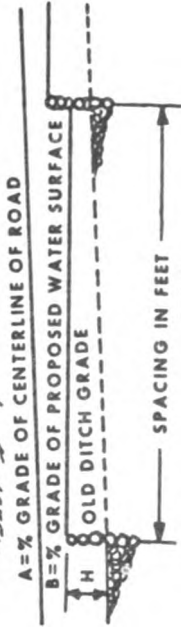
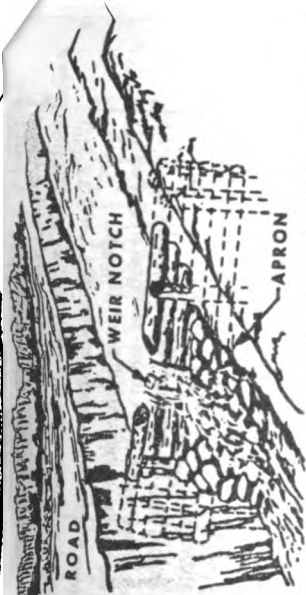
Step 1. "A" Area "What area is draining?"

a. *Delineation--Determining Area and Converting to Acres.*

(1) Use a topo map.

(2) Locate the proposed drainage structure.

(3) Confirm the location and topography by reconnaissance.



$$\text{SPACING} = \frac{100 H}{A - B}$$

**H IS EXPRESSED IN FEET**

Figure 9-4. Methods of computing check dam spacing.

b. *Method of Delineation on Topo Map.*

- (1) Locate proposed or existing structures.
- (2) Locate the high points.
- (3) Draw flowlines from the high points perpendicular to the contours.
- (4) Delineate (outline) the drainage basin.

c. *Methods of Measuring the Area by Use of a Map Scale.*

- (1) Stripper method
- (2) Planimeter method
- (3) Geometric method (sum of rectangles and triangles)
- (4) Convert to acres (1 acre = 43,560 square feet)

Step 2. "R" Rainfall "How much rain can I expect?"

Determine the 1--hour, 2--year frequency rainstorm from the isohyetal map. (inches hour). See figure 9--5.

- (1) Locate applicable geographic area.
- (2) If the area is close to an isohyet, select its value as "R".
- (3) If the area is between two isohyets, select the larger value as "R".

Step 3. "C" Runoff Coefficient "What ratio of water is going to run off?"

- a. Select one of the following values of "C":
  - (1) Impervious (asphalt, concrete, "tight" clay) = 1.0
  - (2) Pervious (well--graded gravel, beach sand) = 0.25
  - (3) All other = 0.5
- b. Or refer to the "C" value, table 9--3.

Step 4. "Q" Runoff in Cubic Feet per Second ( $Q = 2 \text{ ARC}$ )

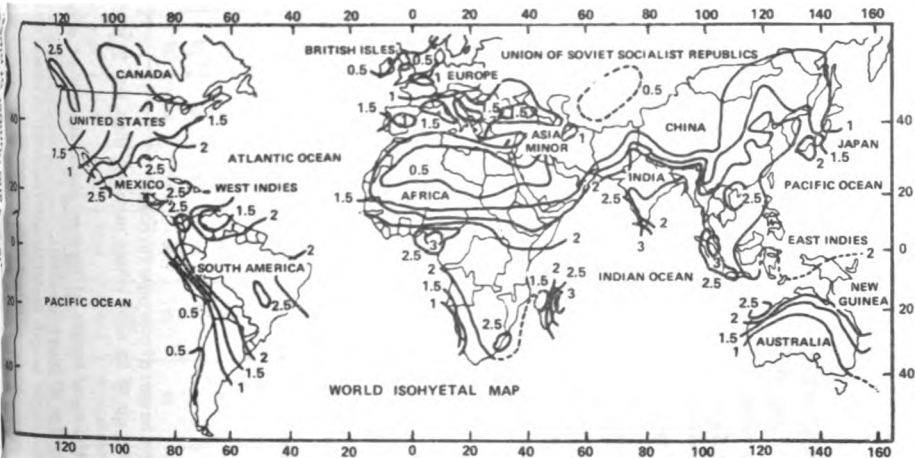
Step 5. Determine Cross--Sectional Area of Water

- a.  $Q = AV$
- b.  $A =$  Cross--sectional area of water in square feet
- c.  $V =$  Velocity, in feet per second; use 4 fps
- d.  $A = \frac{Q}{4}$

Step 6. Culvert Design

- a. Slope should be 0.4% minimum to 2.0% maximum; use 1.0%.
- b. Culvert design area =  $2 \times A$  (cross--sectional area of water).
- c. Find the critical (minimum) fill depth ( $F_{\min}$ ).
- d. Compute the maximum pipe diameter ( $D_{\max} = 2/3 F_{\min}$ ).

Select the maximum pipe diameter that can be used from table 9--4.  
Compute the most economical pipe size and number of pipes:



ISOHYETS REPRESENTS INCHES OF MAXIMUM RAINFALL IN ONE HOUR FOR STORM OF 2-YEAR FREQUENCY

Figure 9-5. World isohyetal map.

Table 9-3. Surface Runoff Factors

Types of surface	Factor
Asphalt pavements	0.80 to 0.95
Concrete pavements	0.70 to 0.90
Gravel or macadam pavements	0.35 to 0.70
Impervious soils*	0.40 to 0.65
Impervious soils, with turf*	0.30 to 0.55
Slightly pervious soils*	0.15 to 0.40
Pervious soils*	0.01 to 0.10
Wooded areas depending on surface slope and soil cover	0.01 to 0.20

\* For slopes from 1 to 2 percent.

*Note.* The figures given are for comparatively level ground. For slopes greater than 1 in 50 (2%) the factor should be increased by 0.2 for every 2 percent of slopes up to a maximum 1.0.

- g. Compute the length of one pipe (in place).

*NOTE:* Round up to an even whole number, then add 2' if there is no headwall downstream.

- h. Compute the total length of pipe in place. (length of one pipe, in place times the number of pipes required).

i. Compute the order length (total length required, in place, times 1.15).

		Gage Pipe required for:						
Diem in Inches	Cross- sectional area (sq ft)	Fills up to 8 ft.	Fills up to 16 ft.	20-ft. fill	25-ft. fill	30-ft. fill	35-ft. fill	40-ft. fill
8	.35	16	16	16	16	16	16	16
10	.55	16	16	16	16	16	16	16
12	.79	16	16	16	16	16	16	16
15	1.23	16	16	16	16	16	16	16
18	1.77	16	16	16	16	16	16	16
21	2.41	16	16	16	16	16	16	16
24	3.14	16	16	16	16	14	14	14
30	4.91	14	14	14	14	12	12	12
36	7.07	14	14	14	12	12	12	10
42	9.82	14	14	12	12	10	10	8
48	12.57	12	12	12	10	8	8	8
54	15.90	12	12	10	8	8	8	8
60	19.84	12	10	8	8	8	8	8
66	23.76	10	10	8	8	8	8	8
72	28.27	10	10	8	8	8	8	8
78	33.18	8	8	8	8	MUST BE DESIGNED FOR THESE FILL HEIGHTS AND OTHERS ABOVE 40 FT.		
84	38.48	8	8	8	8			

**NOTES:** CULVERTS MUST BE STRONG ENOUGH TO CARRY  
WEIGHT OF FILL ABOVE PLUS WEIGHT OF THE  
LIVE LOAD PASSING OVER ROAD.

CULVERTS BELOW LINE SHOULD BE STRUTTED  
DURING INSTALLATION.

### Step 7. Ditch Design

#### a. Guidelines.

- (1) If  $Q > 60$  cfs, use a trapezoidal ditch.
  - (2) If  $Q \leq 60$  cfs, use a triangular (vee) ditch.
  - (3) Slope should be 0.5% to 2.0% without erosion controls.
  - (4) Side slope should be 3:1, 1:1 when cut by grader.
  - (5) Freeboard should be a minimum of 0.5 feet.
- b. *Trapezoidal.* Compute as a rectangle, ignoring side slopes. See figure 9--6. Select width and calculate depth of water (d).

$$(1) \quad A = dw \quad d = \frac{A}{W}$$

$$(2) \quad w = 10 \text{ feet when cut by scraper} \quad d = \frac{A}{10}$$

$$(3) \quad \text{Cutting Depth} = d + 0.5'$$

c. *Triangular.* Select side slopes and calculate depth of water (d). See figure 9--6.

$$(1) \quad A = \frac{1}{2}(BH)$$

$$B = Xd + Yd$$

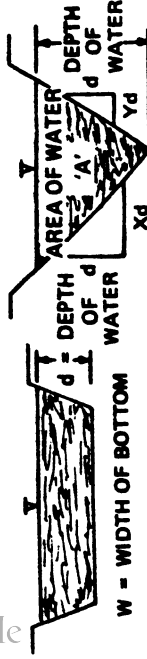
$$H = d$$

$$d = \sqrt{\frac{2A}{x+y}}$$

$$(2) \quad \text{If side slopes 3:1, 1:1}$$

$$d = \sqrt{\frac{A}{2}}$$

$$(3) \quad \text{Cutting depth} = d + 0.5'$$



(b) *By hasty computation method* (Use for an area that has a stream flowing through it).

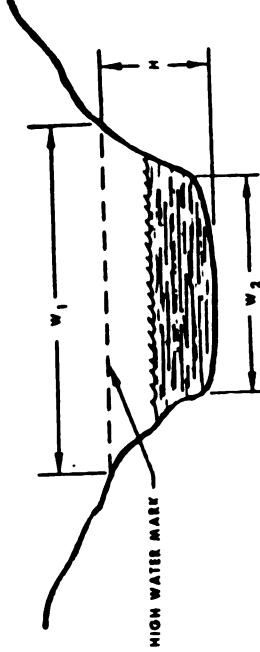
Step 1. Calculating the Design Area. See figure 9-7.

- a. Locate the high water mark.
- b. Measure the width of the stream at the high water mark ( $W_1$ ).
- c. Measure the width of the stream at the bottom ( $W_2$ ).
- d. Measure from the bottom of the stream to the high water mark (H).
- e. Calculate the design area (2 x cross-sectional area).

$$(1) \quad \frac{(W_1 + W_2)}{2} H \times 2$$

or:

$$(2) \quad (W_1 + W_2) H$$



$W_1$  = WIDTH OF CHANNEL AT HIGH WATER MARK

$W_2$  = WIDTH OF CHANNEL AT BOTTOM

$H$  = VERTICAL DISTANCE FROM BOTTOM TO HIGH WATER MARK

$$\left[ \frac{W_1 + W_2}{2} \right] H = \text{AREA OF WATERWAY}$$

SIZE OF CULVERT = AREA OF WATERWAY + SAFETY FACTOR 100%

Figure 9-7. Computation of culvert size by hasty method.



### Step 2. Culvert Design

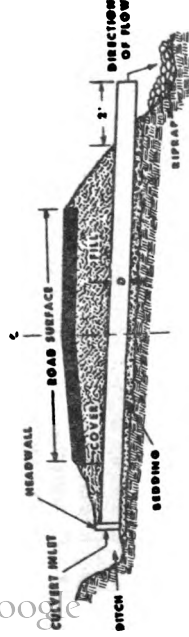
- Find the critical (minimum) fill depth ( $F_{\min}$ ).
- Compute the maximum pipe diameter ( $D_{\max} = 2/3F_{\min}$ ).
- Select the maximum pipe diameter that can be used from table 9-4.
- Compute the most economical pipe size and number of pipes:

#### Design area

End area of one pipe from table 9-4

- Compute the length of one pipe (in place).  
*NOTE:* Round up to an even whole number, then add 2' if there is no headwall downstream.
  - Compute the total length of pipe in place (length of one pipe, in place times the number of pipes required).
  - Compute the order length (total length required, in place, times 1.15).
- (3) *Culvert alignment.* Culverts are placed in natural drainage channels unless such installation would require an unusually long culvert or produce a sharp bend in the channel on the upstream side. Where old drainage channels are not encountered, culverts should be installed at right angles to the road centerline. Ditch relief culverts should be installed at an angle of  $60^{\circ}$  to the ditch centerline.

(4) *Design criteria—CMP culvert.* See figure 9-8.



2 Minimum cover required.

- (c) Minimum cover of  $\frac{1}{2}$ D or 12 inches under the road surface. (table 9-4).
- 3 Culvert available.

(c) Place the inlet elevation at or below the ditch bottom.

(d) Extend the culvert 2 feet minimum downstream beyond the fill slopes.

(e) Use bedding of 1/10D minimum.

(f) Space multiple culverts a minimum of  $\frac{1}{2}$ D apart.

(g) Desirable slope is 2 to 4%, minimum slope, 0.5%.

(h) Always use a headwall upstream.

(i) Rip-rap downstream to control erosion.

(5) *Corrugated metal pipe—size and strength. See table 9-4.*

(6) *Expedient culvert (fig. 9-9).*

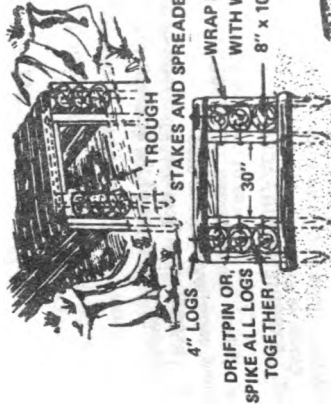
## 9-6. SOIL STABILIZERS

See table 9-5.

## -7. EXPEDIENT SURFACES

- a. When normal means of construction are not available or time is limited, expedients must be used.
- b. Expedient surfaces over mud must be structurally strong and spread the load over a wide area of the subgrade.

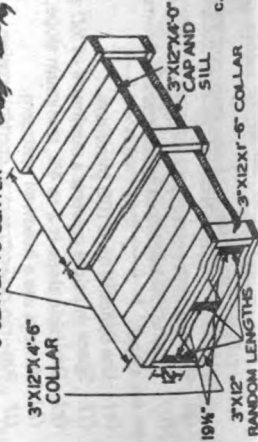
## a. LOG CULVERT



## b. SANDBAG CULVERT



6" CENTER-TO-CENTER

3"X12"X4'-6"  
COLLAR

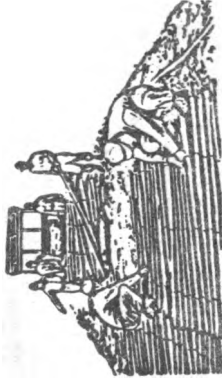
## c. TIMBER CULVERT

MATERIAL	FORM OF MATERIAL	APPLICABLE SOIL RANGE	ESTIMATED RANGE OF PERCENTAGE REQUIREMENTS (%)†	MINIMUM CURING TIME REQUIREMENTS
PORTLAND CEMENT	POWDER	GRAVELS SANDS SILTS, CLAYEY SILTS CLAYS	3-4 3-5 4-6 6-8	24 HOURS
LIME				
1. HYDRATED	POWDER	CLAYEY GRAVELS SILTY CLAYS CLAYS	2-4 5-10 3-8	7 DAYS
2. QUICKLINE	POWDER	CLAYEY GRAVELS SILTY CLAYS CLAYS	2-3 3-8 3-6	4 HOURS
BITUMINOUS MATERIAL:				
1. ASPHALTIC CUTBACKS A. RC-70 TO RC-800	LIQUID	SANDS SILTY SANDS CLAYEY SANDS	5-7++ 6-10 6-10	1-3 DAYS
B. MC-70 TO MC-800	LIQUID	SANDS SILTY SANDS CLAYEY SANDS	5-7 6-10 6-10	1-3 DAYS
2. ASPHALTIC EMULSIONS	LIQUID	SANDS SILTY SANDS CLAYEY SANDS	5-7 6-10 6-10	1-3 DAYS

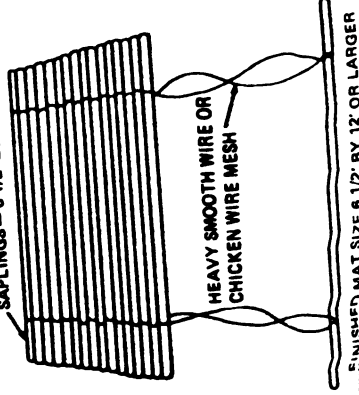
† BASED ON DRY DENSITY OF EXISTING SOIL.

++ ALL QUANTITIES LISTED FOR ASPHALTS ARE ACTUAL BITUMEN REQUIREMENTS, EXCLUSIVE OF VOLATILES.

(1) *Chespaling.* Chespaling—mat roads (fig. 9—10) are composed of a series of mats  $6\frac{1}{2}$  by 12 feet, or larger. The mats are made by placing small saplings  $6\frac{1}{2}$  feet long and about  $1\frac{1}{2}$  inches in diameter side by side, and wiring them together with chicken wire mesh or strands of heavy smooth wire. A chespaling road is constructed by laying mats lengthwise with a 1-foot side overlap at the junction of the mats. The resulting surface is 12 feet wide. Unless laid on wet ground, this type of road requires periodic wetting down to retain its springiness and to prevent splitting. It also requires extensive maintenance.



SAPLINGS —  $6\frac{1}{2}$ ' LONG,  $1\frac{1}{2}$ " DIA



(2) *Corduroy.*

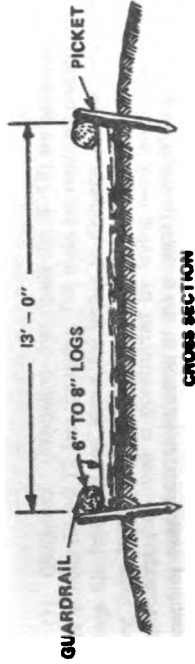
(a) *Standard corduroy (fig. 9-11a).*

Six- to eight-inch-diameter logs about 13 feet long are placed adjacent to each other (butt to tip). Along the edges of the roadway thus formed, place 6 inch diameter logs as curbs (drift-pinned in place). Pickets about 4 feet long are driven into the ground at regular intervals along the outside edge of the road to hold the logs in place. To give this surface greater smoothness, fill up the chinks between logs with brush, rubble, twigs, etc.; then cover the whole surface with a layer of gravel or dirt. Side ditches and culverts are constructed as for normal roads.

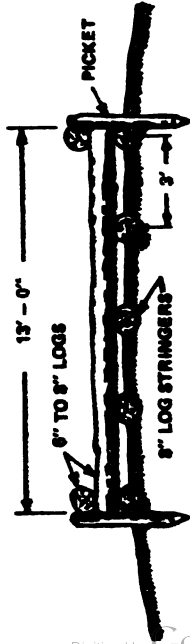
(b) *Corduroy with stringers (fig. 9-11b).* The corduroy decking is securely pinned to stringers and then the surface is prepared as (a) above.

(c) *Heavy corduroy (fig. 9-11c).* Heavy corduroy involves the use of sleepers, heavy logs 10 to 12 inches in diameter and long enough to carry the entire road, placed at right angles to the centerline on 4 foot centers.

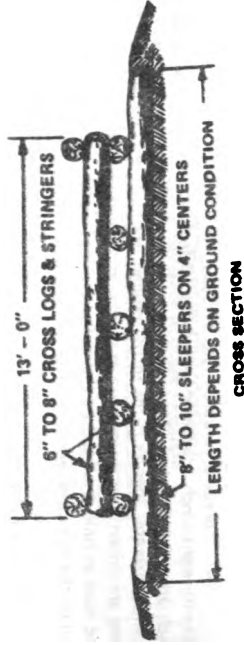
(3) *Tread roads (fig. 9-12).* Tread roads are made by preparing two narrow parallel treadways of select material for vehicular wheels to use over otherwise impassable ground. The material used may be anything from palm leaves to 4 inch planks with a consequent wide variation in the capacity and durability of the road. The most important single type of tread road is the plank tread road. Sleepers 12 to 16 feet long are first laid perpendicular to the centerline, on 3 to 4 foot centers, depending on the loads to be carried and subgrade conditions. If finished timber is not available, use logs as sleepers. Then place 4- by 10-inch planks parallel to the line of traffic to form two treads about 36 inches apart. Stagger the joints to prevent the forming of weak spots. Next install 6- by 6- inch timber curbs on the inside of the treads.



CROSS SECTION

**A. STANDARD CORDUROY**

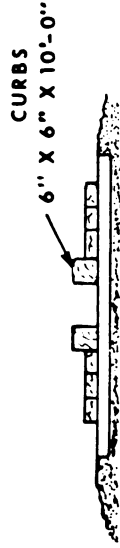
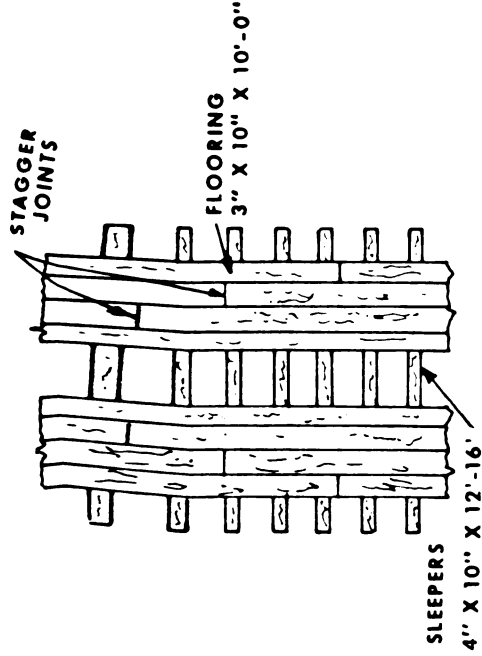
CROSS SECTION

**B. CORDUROY WITH STRINGERS**

CROSS SECTION

**C. HEAVY CORDUROY**

PLAN



CROSS SECTION

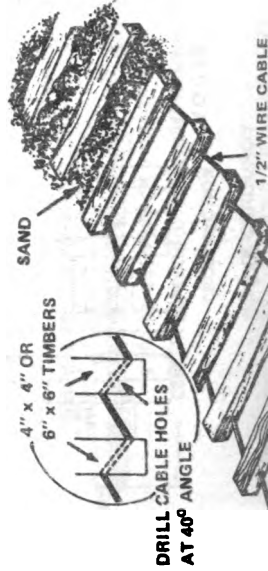
Figure 9-12. Tread road.



c. Expedient surfaces over sand must confine the sand in a manner which will develop the necessary load-carrying capacity.

(1) *Wire mesh.* Chicken wire, expanded metal lath, and chain link wire mesh (cyclone fence) may be used as road expedients in sand. They should not be used on muddy roads since they prevent grading and reshaping of the surface when ruts appear. The addition of a layer of burlap or similar material underneath helps to confine the sand. Any type of wire mesh expedient must be taut. To accomplish this, the edges of the wire mesh road must be picketed at 3--to--4 foot intervals. Diagonal wires, crossing the centerline at 45° angles and attached securely to buried pickets, fortify the lighter meshes. As with all other road surfaces, the more layers used the more durable the road will be.

(2) *Army track (fig. 9-13).* A portable timber expedient known as Army track can be used to pass vehicles across sandy terrain. The track consists of 4 x 4 or larger timbers threaded at each end on a ½-inch wire rope and resembles the ties of a railroad track with a cable running through the ties on each side. The timbers must be spaced not greater than the distance which will allow the smallest wheeled vehicle using the road to obtain traction. Cable holes are drilled at a 45° angle to the centerline so the cable will bend and prevent individual timbers from moving together. Cables are anchored securely at both ends. The spaces between the timbers are filled in with select material to smooth out the surface.



d. *Metal Landing Mats* (Fig. 9-14). Airfield landing mats can be used to form an expedient road surface over either mud or sand. Generally, only M8 and M8A1 would be used in this capacity and, as far as road construction is concerned, their characteristics are the same. When used on sand, the metal landing mats can be placed directly on the sand to the length and width desired, though burlap on straw underneath the planking is desirable. The mat is smoother and firmer the subgrade, the better the resulting road. The mat is placed so that its long axis is perpendicular to the flow of traffic and each section overlaps the previous one enough that the manner of connecting prescribed for the particular mat can be accomplished.

If a width greater than the effective length of one plank is constructed, half-sections are used to facilitate staggering of joints. M8 mat can be used on mud but, being perforated, the mat sinks until it becomes ineffective. Experiments have proven that with the use of an underlying layer of brush or burlap to prevent the pumping of the mud, a fairly effective expedient can be constructed. A second layer of the steel mat, laid as a treadway over the initial layer, will further increase its effectiveness. In either case, the foundation should be as smooth as possible.

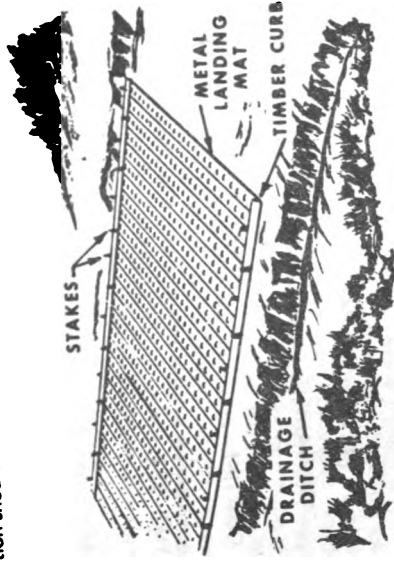


Figure 9-14. Metal landing mat road.

## CHAPTER 10

### ARMY AIRFIELDS, HELIPADS, AND HELIPORTS

#### 10-1. GENERAL

Information listed for airfields is for reference only. For design specifications refer to TM 5-330.

#### 10-2. ARMY AIRCRAFT AND HELICOPTER CHARACTERISTICS

Aircraft and helicopter characteristics are shown in tables 10-1 and 10-2.

#### 10-3. HELIPADS IN HEAVILY FORESTED AREAS

*a. Personnel.* The suggested work crew consists of an officer in charge and two teams, each composed of a noncommissioned officer and five enlisted men -- two chain saw operators, two axemen men, and one brush hook man. Weight of an individual is assumed to be 200 pounds.

*b. Equipment.* The following equipment per team is to be contained in the equipment box. The weight of the box loaded with the equipment is approximately 333 pounds.

2	Chain saws
1	Brush hook
3	Axes
1	Block and tackle set (1 single and 1 double)
1	Set climbers with safety straps
1	Can gasoline
16	2½ lb. Blocks of C-4

- 2 Wedges
- 2 Screwdrivers
- 2 Pliers

c. *Procedure.*

- (1) *Equipment and personnel delivery.* Equipment is delivered into the proposed landing area by lowering it in a box. Modification of the equipment requirements may be desired depending upon the expected area of employment. The box is slung beneath the helicopter by the aircraft cargo hook. Rappelling ropes are then attached to the box and secured to the floor-mounted D-rings inside the helicopter. Since, in the event of an in-flight emergency, the pilot cannot jettison the external load, engineers within the cargo compartment are responsible for cutting or releasing the ropes upon direction by the pilot or copilot. To lower the box to the ground, the cargo hook is released and the box is lowered by hand using the attached rappelling ropes. All personnel in the team are equipped with field equipment, machetes, weapons, and other items which are carried on the person during rappelling activities. Other field gear, if utilized, is inclosed in the equipment box lowered from the helicopter.
- (2) *Preparation of landing zone.*

(a) The first man on the ground removes the rappelling ropes from the equipment box. The officer in charge starts laying out strips of engineer tape to mark the perimeter of the proposed landing area.

(b) The chain saw crews, axe crews, and brush hook man move into the proposed landing area, felling and clearing all vegetation within the perimeter of the tape-marked landing area.

(c) Upon felling the trees as close as possible to ground level, necessary limbing and bucking is done for easier removal. It is imperative that in felling and cutting, any vegetation that may be sucked up into the helicopter blades must be removed from the landing area proper. Vegetation should not be burned. Time permitting, or under marshy conditions, the timbers felled may be used to prepare a hardened landing pad. Landing pad logs are leveled to insure a satisfactory surface upon which the helicopter skids can rest without danger of skid damage. The perimeter of the landing area must be checked to assure vertical clearance. In densely wooded areas

Table 10-1. Aircraft Characteristics Used in Design of Theater of Operations Airfields

Airfield type	Anticipated service life	Possible aircraft U.S. type	Gross weight	Ground run at sea level and 50°, ft <sup>b</sup>	Minimum length required, ft	Width, ft
Battle area: Light lift Medium lift	3 days	C-7A <sup>a</sup>	25,000	625	1,000	50
		C-130 <sup>a</sup>	100,000	1,800	2,000	60
		C-123	48,000	1,600		
Forward area: Liaison Surveillance Light lift Medium lift	2 weeks	O-1 <sup>a</sup>	2,400	380	750	50
		OV-1 <sup>a</sup>	15,800	2,000	2,500	60
		C-7A <sup>a</sup>	28,500	625	1,200	60
		C-130 <sup>a</sup>	110,000	2,000	2,500	60
		C-7A	28,500	625		
Support area: Liaison Surveillance Light lift Medium lift	1-2 mos	O-1 <sup>b</sup>	2,400	380	1,000	50
		OV-1 <sup>b</sup>	15,800	2,000	3,000	60
		C-7A <sup>b</sup>	28,500	625	1,800	60
		C-130 <sup>b</sup>	130,000	2,800	3,500	60
		C-7A	28,500	625		
		C-124 <sup>b</sup>	190,000	4,000	6,000	100
		C-141 <sup>b</sup>	260,000	2,400		
		F-4C <sup>b</sup>	56,000	4,000	5,000	60
Tactical		F-101	51,000	4,000		
Rear area: Army	6-12 mos	OV-1 <sup>a</sup>	15,800	2,000	3,000	72
		C-7A	28,500	625		
		O-1	2,400	380		
		C-130 <sup>b</sup>	156,000	4,900	6,000	72
		C-141 <sup>b</sup>	316,000	3,900	10,000	186
Medium lift Heavy lift		C-135 <sup>a</sup>	260,000	6,700		
		C-133	300,000	5,300		
		F-4C <sup>a</sup>	66,000	4,000		
		F-105 <sup>a</sup>	83,000	5,300		
		F-100	37,800	5,000		
Tactical		F-101	51,000	4,000		
		F-104	28,000	5,200	8,000	108

<sup>a</sup>Particular aircraft that is critical in load and/or ground run from which area requirements, geometries, and expedient surfacing requirements were developed.

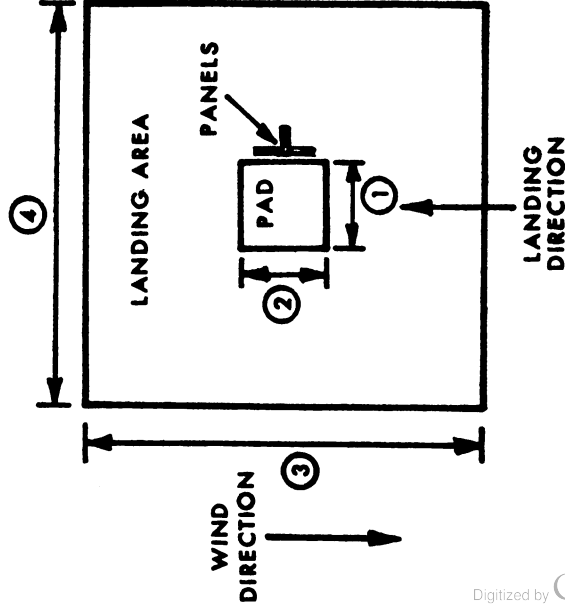
Table 10-2. Helicopter Characteristics

Helicopter Designation		Overall Dimensions Ft			Weight, Kips		Gear Type
Design	Name	Length	Width	Height	Basic	Maximum takeoff	
OH-6A*	Cayuse	30.30	26.30	8.20	1.16	2.70	Skid
OH-13S	Sioux	43.25	37.00	12.00	1.91	2.85	Skid
OH-23G	Raven	43.25	35.16	10.16	1.91	2.80	Skid
OH-58A	Kiowa	41.00	35.30	9.60	1.59	3.00	Skid
UH-1B	Iroquois	52.83	44.00	16.41	5.08	9.50	Skid
UH-1C	Iroquois	52.83	44.00	12.67	4.82	9.50	Skid
UH-1D*	Iroquois	57.01	48.00	17.16	4.92	9.50	Skid
CH-34	Choctaw	65.93	56.00	15.83	7.76	13.30	Single-conventional
CH-37B	Mojave	88.00	72.00	22.00	21.50	31.00	Twin-conventional
CH-47A	Chinook	98.01	59.16	18.50	18.04	33.00	Twin-quad
CH-47B	Chinook	99.00	60.00	18.67	19.59	40.00	Twin-quad
CH-47C	Chinook	99.00	60.00	18.67	20.48	46.00	Twin-quad
CH-54A*	Flying Crane	88.41	72.00	25.33	19.82	42.00	Single-tricycle
AH-1G	Huey Cobra	52.97	44.00	11.00	.....	.....	Skid

and jungle forest, it will be necessary to fell additional trees to provide an approach and departure zone. The normal time for clearing such a landing zone in tropical zone forests by well-trained troops should not exceed 3 hours for a UH-1 and smaller helicopter landing zones.

#### 10-4. LAYOUT AND NOMENCLATURE

Landing reference panels serve as a visual guidance system during approaches. They must be positioned and firmly secured adjacent to the touchdown point before the landing of a helicopter. Figure 10-1 shows correct placement of landing reference panels on the ground. The general layout and nomenclature of Army helipads and heliports is illustrated in figures 10-1 thru 10-3.



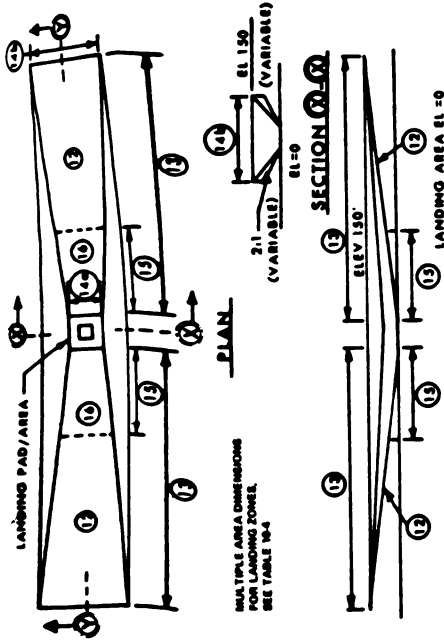
PANELS ARE LAID OUT ON THE RIGHT SIDE OF THE LANDING PAD.

RELATIONS OF THE LANDING AREA CORRELATE

FOR DIMENSIONS TO TABLE 10-3

ITEM NUMBER





FOR GEOMETRIC REQUIREMENTS  
CORRELATE ITEM NUMBERS TO  
TABLE 10-3 AND TABLE 10-4

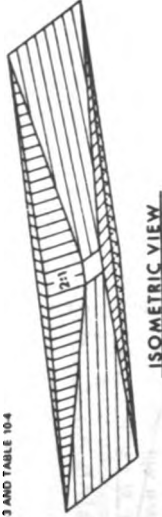


Figure 10-2. Geometric layout of landing zones.





The general design requirements for landing zones and multiple area landing zones are shown Tables 10-3 and 10-4.

## 10-6. DUST CONTROL/SOIL WATERPROOFING

*Sprinkling with water, lime solutions, and oils provide temporary relief from dust. Longer relief is achieved by use of asphaltic materials, such as Penaplime (APSB), or special compounds such as DCA-70. Any asphaltic material must be allowed to cure before being exposed to traffic. Asphaltic cutback materials also serve to waterproof soils. See table 10-5 for approximate area to be sprayed.*

## 10-7. MARKING IMPROVED HELIPADS AND HELIPORTS

The touchdown area marker for helipads is shown in figure 10-4. The dimensions of the pattern relative to the pad size are shown in this figure. The center of the marking pattern will always be placed at the center of the pad. This marking pattern will also be placed at both ends of all runways and taxi-hoverlanes used for landings. This pattern is intended as an indication of a safe touchdown point and is not to be placed at locations, such as parking areas, at which helicopters normally do not land or take off. The marking pattern will be white, but should be edged in black when placed on a light-colored surface. The broken line border around the perimeter of the pad will also be included on all helipads.

## 10-8. LANDING MATS

The types of landing mats and membrane are classified as follows:

- a. Light duty landing mat— M6, M8, M8A1, and M9.
- b. Medium duty landing mat— MX188, MX19, and AM2.
- c. Membrane— T17.

Table 10-3. Minimum Geometric Requirements for Landing Zones.

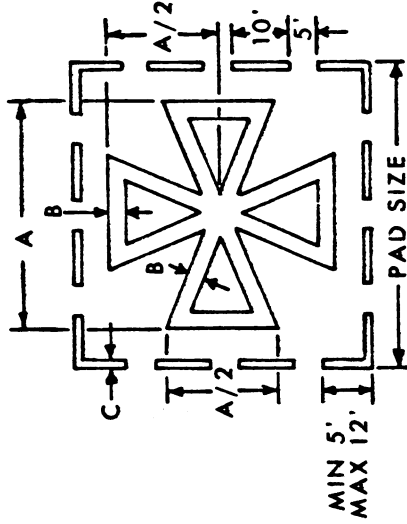
Item No.	Description	FORWARD AREA					
		OH 6A	OH 58	AH-1G	UH-1H	CH-47	CH-54
LANDING PAD AND LANDING AREA							
1	Length, ft .....	12	15	20	20	60	50
2	Width, ft .....	12	15	20	20	25	50
3	Landing area length, ft .....	72	84	100	100	150	150
4	Landing area width, ft .....	72	84	100	100	125	150
5	Parking pad grade in any direction, % Maximum .....	3	3	3	3	3	3
6	Lateral clearance from rear and sides of parking pad to fixed and/or movable obstacles except other aircraft, ft .....	25	30	45	45	65	65
7	C-C spacing of parking pads, ft .....	40	50	75	75	150	150
8	Spacing from edge of Taxi-Overlane to edge of parking pad, ft .....	25	30	45	45	65	65
TAXI HOVERLANE							
9	Width, ft <sup>1</sup> .....	75	90	140	140	180	200
10	Longitudinal grade of Taxi-Overlane, % Maximum .....	10	10	10	10	10	10
11	Transverse grade of Taxi-Overlane % Maximum .....	5	5	5	5	5	5
HELIPORT APPROACH AND DEPARTURE ZONE							
12	Approach-departure surface ratio .....	10:1	10:1	10:1	10:1	10:1	10:1
13	Length, ft .....	1500	1500	1500	1500	1500	1800
14	Widths, ft .....						
	a. At end of clear zone or Taxi-Overlane .....	75	90	140	140	180	200
	b. At outer end .....	850	950	850	850	850	850
HELIPORT TAKEOFF SAFETY ZONE							
15	Length, ft .....	500	500	500	500	500	500
16	Width, ft .....	SAME AS APPROACH DEPARTURE ZONE					
SERVICE ROADS							
17	Width, ft <sup>2</sup> .....	11.5	11.5	11.5	11.5	11.5	11.5

Item No.	Description	Forward area	
		UH-1	CH-47
1	One-ship landing zone		
	Length .....		
	Width .....		
2	Two-ship trail landing zone		
	Length .....	100	150
	Width .....	100	125
3	Two-ship side-by-side landing zone		
	Length .....	180	250
	Width .....	100	125
4	Three-ship trail landing zone		
	Length .....	100	150
	Width .....	170	220
5	Four-ship side-by-side trail		
	Length .....	260	375
	Width .....	100	125
		180	250
		170	220

Table 10-5. Dust Control Requirements for Heliports

Area	Dimension of area requiring dust control (ft)			
	OH-6A Cayuse	UH-1D Iroquois	AH-1G Huey Cobra	CH-47A Chinook CH-54A Skycrane
Taxi-hover Lane and Parking Pads .....	75	75	80	150
	80	132	150	216
Takeoff and Landing Areas .....				

NOTE: Measurements are taken from the center of rotation of the controlling aircraft and are approximately equal to the radius of the area affected by the rotor downwash.



PATTERN SIZE (A) IS 0.80 HELIPAD SIZE

### DIMENSIONAL CRITERIA

HELIPAD SIZES	PATTERN LINE WIDTH (B)	BORDER EDGE WIDTH (C)
FEET	FEET	FEET
12-19	1.0	0.5
20-40	2.0	1.0
41-60	3.0	1.5
61-80	4.0	2.0
81-99	5.0	2.0

a. *7-17 Membrane.* When a tear occurs in the membrane surfacing on which antiskid compounds have been applied, the failed area should be repaired by slitting it in the form of an X and folding the four flaps back. Adequate membrane surfacing should then be removed from a roll of membrane and placed beneath the antiskid coated membrane so that it extends beyond the failed area of surfacing for approximately 2 ft on all sides. Adhesive should then be applied to the top of the membrane removed from the membrane roll and to the bottom of the surfacing coated with antiskid compound. Adhesive can be spread over the membrane with long handled paint rollers. After the adhesive becomes tacky (2 to 5 minutes), the flaps that were folded back previously should be placed in their original positions, and the adhesive should be allowed to set for approximately 15 minutes. The patched area should then be rolled with a jeep. This manner of patching should also be used for areas of surfacing that are not coated with antiskid compound, but surface patches can be used on uncoated membrane, particularly when the opening being patched is small.

b. *M8AJ and M8 Mats:*

(1) *Removal.*

- (a) Unlock the end connector bars (hooks) at both ends of the panel to be removed.
- (b) Remove the 12 (6 per side) side connector locking lugs that hold the panel. (Break the weld on the locking lugs of the M8.)
- (c) Drive the panel laterally (approximately 1 inch) until the side connector hooks are centered in the side connector slots.
- (d) Pry the side connector hooks out of the slots.
- (e) Drive the panel laterally to clear the end from the overlapping end of the adjacent panel.
- (f) Remove the panel from the runway.

(2) *Replacement.*

- (a) Remove the side connector locking lugs of a new panel (break the welds on the M8) to allow the panel to slide laterally when positioned properly. Orient the new panel in all respects so that it will be in the approximate position in the run of that of the damaged panel.

(b) Drive the end of the new panel under the end of the adjacent panel so that the adjacent panel will overlap the new panel. (The panel will then be in its approximate final position.)

(c) Adjust the panel to align the side connector hooks with the side connector slots. Engage the two by hammering together.

(d) Drive the panel laterally (in the same direction in which panels in the same run were slid during initial placement) to hook the side connectors.

(e) Lock the end connectors bars (hooks on the M8) at both ends of the panel.

(f) Replace and engage the side connector locking lugs in the locking lug slots (reweld on the M8).

#### c. AM2 Mat and XM18B.

##### (1) Sliding method.

(a) With a tooth of the harrow on a motor patrol or with other power equipment, engage a panel end in the same run with the damaged panel and force the entire run to slide out until the damaged panel clears the runway or taxiway edge.

(b) Disconnect the ends of all panels that have been slid from the runway by removing the end connector bars.

(c) Discard the damaged panel. Connect a new panel in its place and lock at the end with the adjacent panel in the run. With a tooth of the motor patrol harrow, engage the panel end and slide the panel until only 2 to 4 in. of the new panel protrude past the edge of the runway.

(d) Reinstall succeeding panels as in step (c) until all panels in the run are in their original position.

##### (2) Cutting method.

(a) Cut the damaged panel in seven places, as shown in figure 10-5.

(b) With a pry bar, force up cut No. 4 and hinge out one side of the



(c) Force up and hinge out the opposite side.

(d) Force out the end connector bars, and remove the two triangular parts by forcing down or up and out. (The adjacent panels can be removed more easily.)

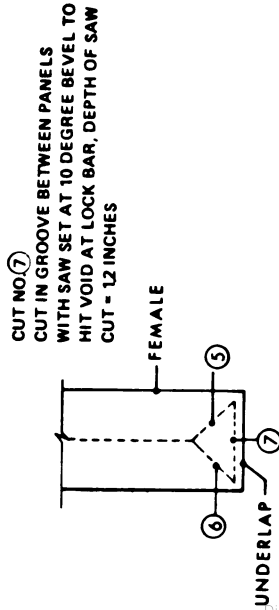
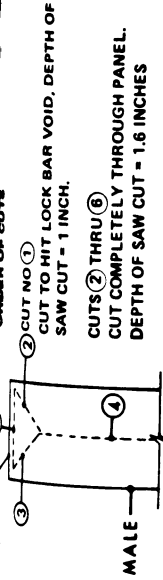


Figure 10-5. Cutting method for removing AM2 or XM18 landing mats.

- (f) Place the accessories in the void and connect and align in such a way that the panel will fit on top of (overlap) two edges and hinge on a third edge.
- (g) Engage the hinge on the panel and drop into position. (The normal underlapping end of the panel contains an end connector bar, recessed to prevent interference when dropped into position and secured with two setscrews.) Remove the screws and use a pointed rod to work the end connector bar into the slot of the adjacent panel. Replace the setscrews and screw down along the side edge of the end connector bar to prevent the bar from disengaging.
- (h) Place the top rail for the side and secure with countersunk allen screws.



d. XM19 Mat.

(1) Cutting method.

- (a) Cut the damaged panel in four places as shown in fig. 10-6.
- (b) With a pry bar, force up one of the triangular cuts.
- (c) Pry up the remaining three pieces.

(2) Replacement.

- (a) Place the replacement panel in the void and engage the hinges.
- (b) Place the connector bar in the slot and secure the countersunk allen screws.

e. *Subgrade Failure.* Subgrade failure normally requires removal of material and replacement with a better quality material. When subgrade failure occurs in an area that is not readily accessible by disassembly of matting, then procedures stated in paragraph 10-9 a thru d can be utilized to gain access to the area to be repaired.

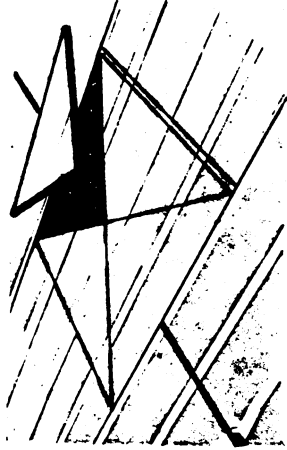


Figure 10-6. Damaged panel of XM19 landing mat cut for removal from mat field.

## RIGGING

## 11-1. FIBER AND WIRE ROPES

a. *Data.* See tables 11-1 and 11-2 for data on manila, sisal, and wire rope.

b. *Safety Factors.* The safety factors normally used with wire rope are given in table 11-3. Where age and condition of rope are doubtful, or where human life or expensive equipment may be endangered by rope failure, apply a safety factor of at least 8.

c. *Safe Working Capacity.* The following general formula can be used to compute safe working capacities.

$$\text{Fiber Rope: } T = \frac{4D^2}{\text{Safety Factor}}$$

$$\text{Wire Rope: } T = \frac{32D^2}{\text{Safety Factor}}$$

Where:

T = Safe working capacity in tons

D = Nominal rope diameter in inches

## 11-2. MECHANICAL ADVANTAGES OF VARIOUS BLOCK ARRANGEMENTS

a. *Block and Tackle.* Figure 11-1 shows examples of typical tackle systems. A simple tackle system advantage is figured by counting the number of lines leaving the load (fig. 11-1).

(1) ① — Mechanical advantage of 2

(2) ② — Mechanical advantage of 3

(3) ③ — Mechanical advantage of 5

(4) In a compound system with 5 lines leaving the load (④), fig. 11-1, and the fall line of this tackle attached to a traveling block with 2 lines supporting it, the mechanical advantage is 2 times 5, or 10.

Table 11-1. Properties of Manila and Sisal Rope

Nominal diameter, in.	Circumference, in.	Lbs. per ft.	No. 1 manila		Sisal	
			Breaking strength, tons	Safe working capacity tons (F.S. = 4)	Breaking strength, tons	Safe load, tons (F.S. = 4)
¼	¾	0.20	0.30	0.07	0.24	0.06
⅜	1½	.040	0.67	0.16	0.54	0.13
½	1¾	.075	1.32	0.33	1.06	0.26
⅝	2	.133	2.20	0.60	1.78	0.44
¾	2¼	.167	2.70	0.67	2.16	0.54
7⁄8	2½	.186	3.85	0.96	3.08	0.77
1	3	.270	4.50	1.12	3.60	0.90
1¼	3½	.360	6.00	1.50	4.80	1.20
1½	3¾	.418	6.75	1.69	5.40	1.35
1¾	4¼	.600	9.25	2.31	7.40	1.86
2	5	.895	13.25	3.31	10.60	2.65
2½	6	1.08	15.50	3.87	12.40	3.10
3	7	1.35	23.25	5.81	18.60	4.66
3½	9	2.42	32.00	8.00	26.60	6.40

## NOTES:

1. Breaking strength and safe loads given are for new rope used under favorable conditions. As rope ages or deteriorates, progressively reduce safe loads to one-half of those given.

Table 11--2. Breaking Strength of 6 x 19 Standard Wire Rope

Diameter in. <sup>2</sup>	Approximate weight lb/ft	Iron	Breaking strength, tons of 2000 lbs			
			Traction steel	Plow steel	Improved plow steel	Extra improved plow steel
¾	0.10	1.4	2.6	2.39	2.74	
¾	0.23	2.1	4.0	5.31	6.10	7.56
¾	0.40	3.6	6.8	9.35	10.7	13.3
¾	0.63	5.5	10.4	14.5	16.7	20.6
¾	0.90	7.9	14.8	20.7	23.8	29.4
¾	1.23	10.6	20.2	28.0	32.2	39.8
1	1.60	13.7	26.0	36.4	41.8	51.7
1½	2.03	17.2	32.7	45.7	52.6	65.0
1½	2.50	21.0	40.6	56.2	64.6	79.9
1½	3.60	29.7	56.6	80.0	92.0	114.0
2				108.0	124.0	153.0
				139.0	160.0	198.0

<sup>1</sup>6 x 19 means rope composed of 6 strands of 19 wires each.

<sup>2</sup>Breaking Strength of 6 x 7 or 6 x 37 wire rope is 94% of the breaking strength of a 6 x 19 rope of an equal diameter and identical material.

Example:

Find breaking strength of 1½ inch, 6 x 7, Improved Plow Steel wire rope

Breaking strength of 6 x 19, 1½ inch, Improved Plow Steel wire rope = 64.6 tons

Breaking strength (6 x 7) = .94 x 64.6 = 60.7 tons

Table 11-3. Wire Rope Safety Factors

Type of service	Minimum safety factor
Track cables	3.2
Guys	3.5
Miscellaneous hoisting equipment	5.0
Haulage ropes	6.0
Derricks	6.0
Small electric and air hoists	7.0
Slings	8.0

\*Where age and condition of rope are doubtful, or where human life or expensive equipment may be endangered by rope failures, apply a safety factor of at least 8.

(5) A more complicated compound system (⑤, fig. 11-1) is made up of two simple systems, each of which has 4 lines supporting the load. The traveling block of the first simple system is fastened to the fall line of the second simple system, and the mechanical advantage of this compound system is 4 times 4, or 16.

b. *Chain Hoists.* With a chain hoist, a load can remain stationary without requiring attention, and the hoist can be operated by one man to raise loads of several tons.

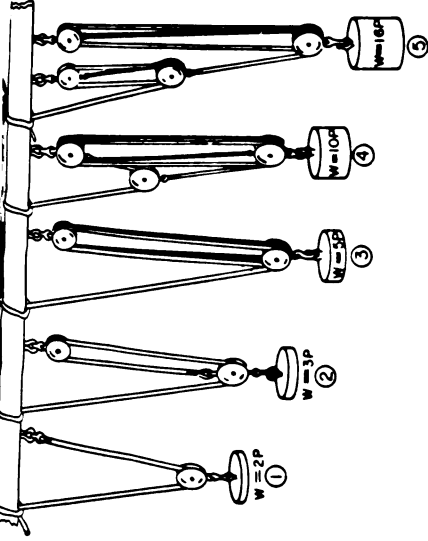


Figure 11-1. Mechanical advantage of various tackle riggings.

c. *Determining Actual Pull.*

FL = friction loss, the amount of force lost to friction in the system.

AP = actual pull, the amount of force required on the fall line to lift the load.

Ff = friction factor, varies with conditions of the blocks.

1/10, excellent condition (new)

1/8, good condition

1/5, fair condition

$N_s$  = number of sheaves, total number of sheaves in the system including change-of-direction blocks.

MA = theoretical mechanical advantage

$W_L$  = weight of the load

Example: Assume

$$W_L = 2500 \text{ lbs}$$

$$N_S = 6$$

$$MA = 6:1$$

$$Ff = 1/5$$

Then

$$FL = W_L \times N_S \times F_f$$

$$= 2500 \text{ lbs (6) (1/5)}$$

$$= 3000 \text{ lbs}$$

And

$$AP = \frac{WL + FL}{MA}$$

$$= \frac{2500 + 3000}{6}$$

$$6$$

$$= 916.67 \text{ lbs}$$

### 11. 3. PICKET HOLDFAST

a. *Holding Power.* Sound pickets, 5 feet long, 3 in. in diameter, driven 3 feet into the earth, spaced 3 to 6 feet apart, and inclined away from the load at an angle of  $15^\circ$ , should stand the pull indicated in table 11-4.

Table 11-4. Picket Holdfast Capacities

Type of holdfast	Undisturbed earth	Wet clay and gravel	Wet river clay and sand
Single picket		630	360
1-1 Picket holdfast	700	1260	700
1-1-1 Picket holdfast	1400	1620	900
2-1 Picket holdfast	1800	1800	1000
3-1 Picket holdfast	2000		

**1800 LB**



**1-1-1 COMBINATION**

*Figure 11-2. Picket holdfast 1-1-1 combination.*

c. *Picket Holdfast, 3-2-1 Combination (fig. 11-3)*

**4000 LB**



**3-2-1 COMBINATION**

*Figure 11-3. Picket holdfast, 3-2-1 combination.*

**11-4. DEADMAN (fig. 11-4)**

Deadman may be constructed of logs, timbers, or steel beams. For complete design procedures refer to TM 5-210.



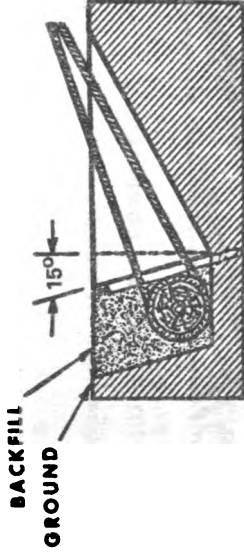


Figure 11-4. Log deadman.

## 11-5. ATTACHMENTS

*a. Clips.* Clips are used in making eyes in wire ropes. The correct method of attaching clips is shown in figure 11-5. The base of each clip should bear against the running end or long line, and the U-bolt against the standing end or short line. The number and spacing of clips and the proper torque to be applied are shown in table 11-5.

*b. Wedge Socket (fig. 11-6).* The wedge socket is used when the fitting must be changed at frequent intervals. This socket has two parts, the socket proper with a tapered opening for the wire rope and a small wedge to go into this socket. The wire rope must be inserted in the wedge socket so that the running part of the rope will form a nearly direct line to the clevis of the

Table 11-5. Number, Size, Spacing, and Torque of Clips for Wire Rope Assembly (Probable Efficiency Factor = 80%)

Wire rope diameter		Nominal size of clips (inch)	Number of clips	Spacing of clips		Torque to be applied to nuts of clips (ft.-lb.)(m.-kg x 0.1382)
(inch)	(mm)			(inches)	(mm)	
5/16	(7.95)	3/8	3	2	(50)	25 (3.5)
3/8	(9.52)	3/8	3	2 1/4	(57)	25 (3.5)
7/16	(11.11)	1/2	4	2 3/4	(70)	40 (5.5)
1/2	(12.70)	1/2	4	3	(76)	40 (5.5)
5/8	(15.85)	5/8	4	3 3/4	(95)	65 (9.0)
3/4	(19.05)	3/4	4	4 1/2	(114)	100 (14)
7/8	(22.22)	1	5	5 1/4	(133)	165 (23)
1	(25.40)	1	5	6	(152)	165 (23)
1 1/4	(31.75)	1 1/4	5	7 1/2	(190)	250 (35)
1 3/8	(34.92)	1 1/2	6	8 1/4	(210)	375 (52)
1 1/2	(38.10)	1 1/2	6	9	(230)	375 (52)
1 3/4	(44.45)	1 3/4	6	10 1/2	(267)	560 (78)

NOTE. The spacing of clips should be six times the diameter of the wire rope. To assemble end-to-end connection the number of clips indicated above should be increased by two, and the proper torque indicated above should be used on all clips; U-bolts are reversed at the center of connection so that the U-bolts are on the dead (reduced load) end of each wire rope.



Figure 11-5. Wire rope clips.

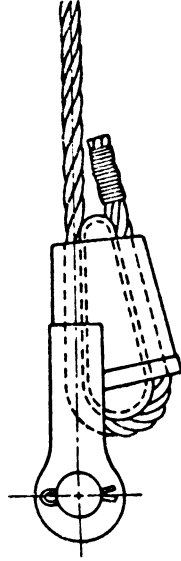


Figure 11-6. Wedge socket and fitting.

## 11- 6. SLINGS

### a. Single Slings.

- (1) A basket hitch is a single sling passed under the load with both ends hooked over the hoisting hook (A, fig. 11-7).
- (2) Single slings with two hooks are sometimes used for lifting stone and 55 gallons drums (B, fig. 11-7).
- (3) The double anchor hitch is used sometimes for hoisting cylindrical objects (C, fig. 11-7).

### b. Endless slings.

- (1) The anchor, or choker, hitch is a common method of using an endless sling by casting the sling under the load and inserting one loop through the other and over the hoisting hook (D, fig. 11-7).
- (2) For a basket hitch, the endless sling is passed around the object and both remaining loops are slipped on the hook (E, fig. 11-7).
- (3) The toggle hitch is a modification of the basket hitch and is used only for special application (F, fig. 11-7).

## 11- 7. SLING LOAD FORMULA

$$t = \frac{W}{N} \times \frac{L}{V}$$

where

$T$  = tension, in lbs

$N$  = number of legs

$W$  = weight of load in lbs

$V$  = vertical distance, in ft

$L$  = length of leg, in ft

c. *Example Problem.* Is it safe to use a  $\frac{3}{4}$ -inch-diameter manila rope sling to lift a 2,000-pound load with a 4-leg sling which has a vertical distance of 6 feet and length of leg of 12 feet (fig. 11-8)?

$$T = \frac{W}{N} \times \frac{L}{V}$$

$$T = \frac{2,000}{4} \times \frac{12}{6} = 1,000 \text{ pounds.}$$

The tension on each leg will be 1,000 pounds. The safe working capacity of  $\frac{3}{4}$ -inch-diameter manila rope from table 11-1 is 0.67 tons or 1,340 lbs. Since the safe working capacity is greater than the tension, the rope is safe to use.

## 11-8. HELICOPTER SLING DESIGN

a. *Strength of Sling.*

(1) For a single leg sling, the minimum safe load capacity should be twice the weight of the load.

(2) For a multiple leg sling, *each leg* should have a minimum safe load capacity equal to the weight of the load.

b. *Length of Sling Legs.* The length of each sling leg should be the same as the greatest dimension of the load ( $L$  max).

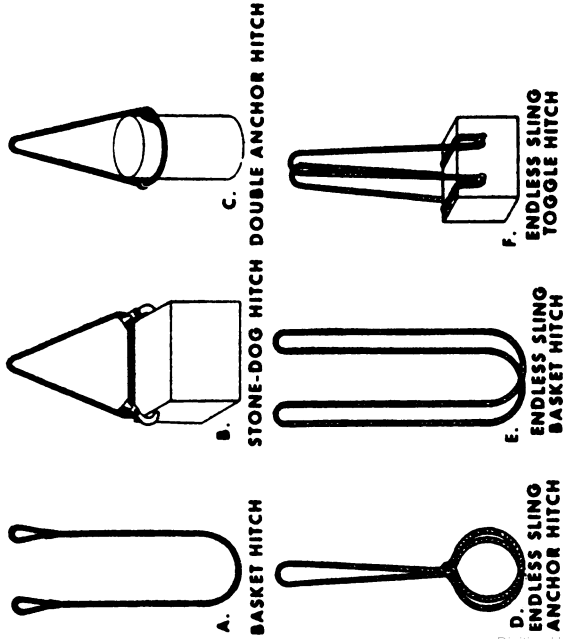


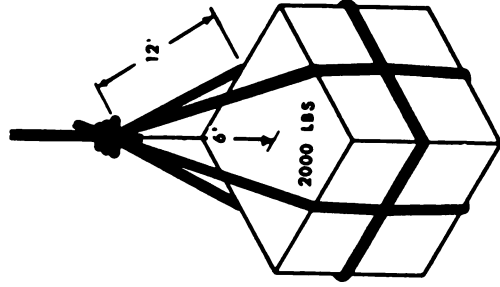
Figure 11-7. Hitches.

c. **Stabilization of Loads.** Helicopter sling loads are stabilized by one or more of the following methods:

- (1) Reduce the air speed of the helicopter.
- (2) Increase the weight of the load.
- (3) Increase the surface area to the rear of the

helicopter when it is in the air.

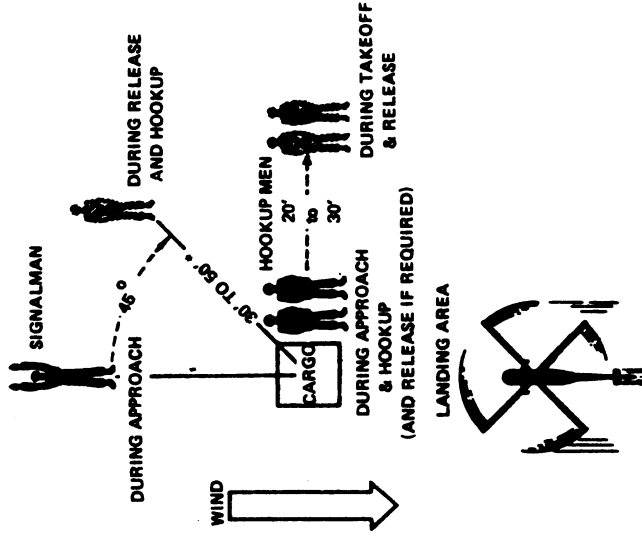
- (1) Pedding should be placed on the sling where rubbing may occur.
- (2) To prevent in-flight "flapping" of prefabricated nylon slings, twist each sling leg one turn for every 3 feet of length.
- (3) The distance between the top of the load and the bottom of the helicopter should be a minimum of 9 feet.



*Figure 11-8. Sling Stresses.*

## 11-9. GROUND CREW

- a. *Positioning.* See figure 11-9.
- b. *Hand Signals.* See figure 11-10.



EMERGENCY

HELICOPTER MOVES LEFT

EMERGENCY

ALL GROUND PERSONNEL MOVE RIGHT  
 • THIS DISTANCE MAY VARY, DEPENDENT UPON THE SPECIFIC ENVIRONMENT,  
 E.G., TERRAIN FEATURES, WEATHER CONDITIONS, AND TYPE OF HELICOPTER  
 EMPLOYED.

Figure 11--9. Position diagram for hook--up/release of helicopter sling loads

## SIGNALS FOR DIRECTING HELICOPTERS



Figure 11-10. Hand signals.



c. *Safety.* Police area thoroughly.

(1) Ground personnel should wear:

(a) Steel helmets.

(b) Protective masks, or dust goggles with respirator.

(c) Earplugs.

(2) Helicopters acquire a large charge of static electricity during flight. A static discharge probe, which is not issued, is used to neutralize the charge. The probe consists of an insulated contact rod joined to a 15'-25' length of metallic tape or wire, which in turn is attached to a ground rod. The ground rod is driven into the earth and the contact rod is held by a ground crewman and touched to the helicopter hook, thus grounding out the stored electrical charge. The ground crewman should not grasp the hook to released the probe. Likewise, the sling should be attached without grasping the hook.

#### 11-10. SAFE CAPACITY OF SPRUCE TIMBER AS A GIN POLE

See table 11-6 for these capacities. Approximate weight of timber is 40 pounds per cubic foot.

Table 11-6. *Safe Capacity of Spruce Timbers as Gin Poles in Normal Operations*

Size of timber, in.	Safe capacity for given length of timber, lbs					
	20 ft (6 m)	25 ft (7.5 m)	30 ft (9 m)	40 ft (12 m)	50 ft (15 m)	60 ft (18 m)
6 dia	5,000	3,000	2,000			
8 dia		11,000	8,000	5,000	3,000	
10 dia	31,000	24,000	16,000	9,000	6,000	9,000
12 dia			31,000	19,000	12,000	
6 x 6	6,000	4,000	3,000			
8 x 8		14,000	10,000	6,000	4,000	
10 x 10	40,000	30,000	20,000	12,000	8,000	
12 x 12			40,000	24,000	16,000	12,000

NOTE: Safe capacity of each leg of trifold is seven-eighths of the value given.

Shears are used to erect heavy machinery and bulky objects. Figure 11-11 shows the proper construction of shears. Shears must be guyed to hold their position and are designed to work inclined from the vertical.

*a. Material.* Maximum shear leg length is 80 times the least diameter of the leg. This ratio must be reduced for extremely heavy loads.

*b. Erection.* Holes should be dug and the shear legs placed in them. This will prevent spreading of the legs. On hard surfaces, the legs should be level and lashed together to prevent spreading. Maximum spread at the base of the legs should not exceed  $\frac{1}{2}$  the height.

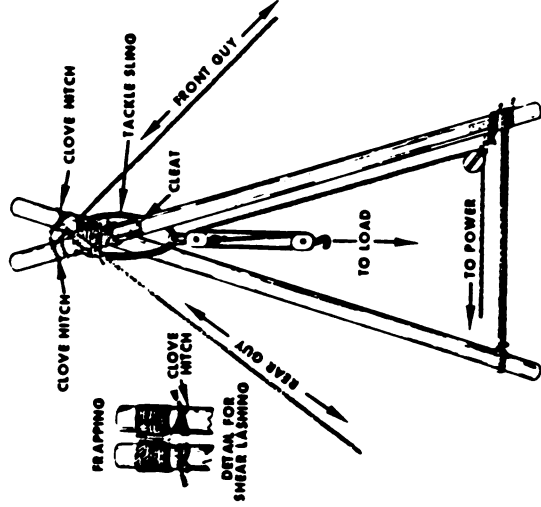


Figure 11-11. Lashing for shears.

## 11--12. GIN POLE

*a. Description.* A gin pole is an upright spar, guyed at the top to hold it in a vertical or near-vertical position, and equipped with suitable hoisting tackle. It is easily rigged, moved, and operated (fig. 11--12).

*b. Erecting.* A gin pole 30 or 40 feet long may be raised easily by hand, but longer poles must be raised by supplementary rigging or power equipment. Figure 11--12 shows the gin pole in position for operation, while the necessary rigging is illustrated in figure 11--13. The maximum allowable length is 60 times the minimum diameter. Guys are 3 to 4 times the pole length.

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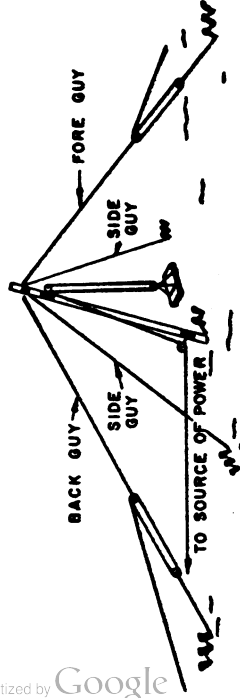


Figure 11--12. Gin pole ready for operation.

## 11- 13. BOOM DERRICK

*a. Rigging.* Booms are used on gin poles to lift loads at a distance from the base of the pole. The boom is two-thirds the length of the gin pole. For heavy loads, lower the butt of the boom to the ground. Raise it for lighter loads; however, it must not bear against the upper two-thirds of the pole.

*b. Operations.* It is a convenient means for loading and unloading

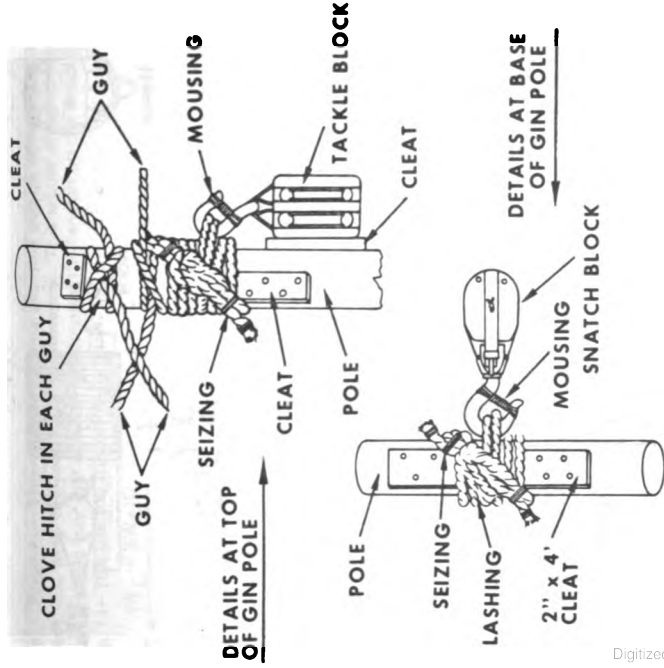
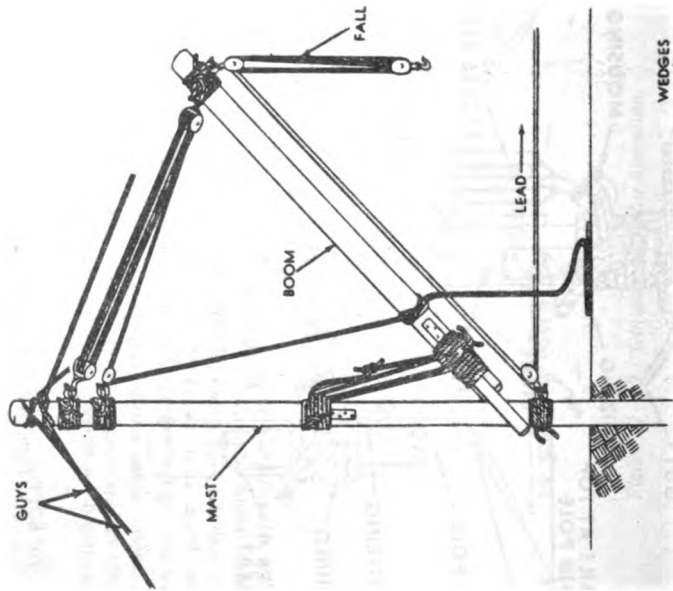


Figure 11-13. Lashing for gin pole.



a. *Tensions.* The most stress on a guy line occurs when a guy line is in direct line with the load and the structure. This would always be the case when a single guy line is used. To compute the tension on the single guy line (fig. 11-15), use the following formula:

$$T = \frac{(W_L + \frac{1}{2}W_S)D}{Y}$$

Where:

T = tension in guy line

$W_L$  = weight of load

$W_S$  = weight of spar

D = drift distance

Y = perpendicular distance .

b. *Example Problem.*

Given:

Load = 2,500 lbs.

Weight of spar = 800 lbs.

Drift distance = 10 feet

Y - distance = 20 feet

Solution:

$$T = \frac{[2,500 + \frac{1}{2}(800)] 10}{20}$$

T = 1,450 lbs.

11-15. KNOTS

For the more common knots, see figure 11-16.

11-16. CHAINS

For safe working loads, see table 11-7.

11-17. HOOKS

For safe loads on hooks, see table 11-8 and figure 11-17.

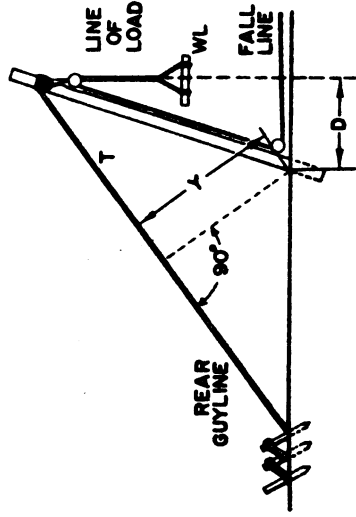


Figure 11-15. Computing tension in single guylines.

Table 11-7. Properties of Chains (Factor of Safety 6)

Size*	Approximate weight per linear foot in pounds	Safe working load in pounds			
		Common iron	High grade iron	Soft steel	Special steel
1/4	0.8	512	563	619	1,240
3/8	1.7	1,350	1,490	1,650	3,200
1/2	2.5	2,250	2,480	2,630	5,250
5/8	4.3	3,470	3,810	4,230	7,600
3/4	5.8	5,070	5,580	6,000	10,500
7/8	8.0	7,000	7,700	8,250	14,330
1	10.7	9,300	10,230	10,600	18,200
1 1/8	12.5	9,871	10,858	11,944	21,500
1 1/4	16.0	12,186	13,304	14,634	26,300






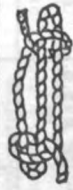

NAME	ILLUSTRATION	USE
SQUARE		JOIN TWO ROPES OF SAME SIZE. (WILL NOT SLIP, BUT WILL DRAW TIGHT UNDER STRAIN.) TO END BLOCK LASHING.
DOUBLE SHEET BEND		JOIN WET ROPES, OF UNEQUAL SIZE, OR ROPE TO AN EYE. (WILL NOT SLIP OR DRAW TIGHT UNDER STRAIN.)
BOWLINE		FORM A LOOP. (WILL NOT SLIP UNDER STRAIN AND IS EASILY UNLITED.)
TIMBER HITCH		LIFTING OR DRAGGING HEAVY TIMBERS. (IS MORE EASILY CONTROLLED IF SUPPLEMENTED BY HALF HITCHES.)
CLOVE HITCH		FASTEN ROPE TO PIPE, TIMBER, OR POST. (IT IS USED TO START AND FINISH ALL LASHINGS AND MAY BE TIED AT ANY POINT IN ROPE.)
SHEEP SHANK		SHORTEN ROPE OR TAKE LOAD OFF WEAK SPOT IN ROPE.
FISHERMAN'S BEND		TO FASTEN CABLE OR ROPE TO ANCHOR.

Figure 11-16. Knots.

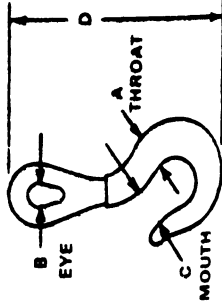


Table 11-8. Safe Loads on Hooks

DIAMETER OF METAL A, IN.	INSIDE DIAMETER OF EYE B, IN.	WIDTH OF OPENING C, IN.	LENGTH OF HOOK D, IN.	SAFE WORKING CAPACITY OF HOOKS, LB.
1 1/16	7/8	1 1/16	4 15/16	1,200
3/4	1	1 1/8	5 13/32	1,400
7/8	1 1/8	1 1/4	6 1/4	2,400
1	1 1/4	1 3/8	6 7/8	3,400
1 1/8	1 3/8	1 1/2	7 5/8	4,200
1 1/4	1 1/2	1 11/16	8 19/32	5,000
1 3/8	1 5/8	1 7/8	9 1/2	6,000
1 1/2	1 3/4	2 1/16	10 11/32	8,000
1 5/8	2	2 1/4	11 27/32	9,400
1 7/8	2 3/8	2 1/2	13 9/32	11,000
2 1/4	2 3/4	3	14 13/16	13,400
2 5/8	3 1/8	3 3/8	16 1/2	17,000
3	3 1/2	4	19 3/4	24,000

•FOR REFERENCE TO A, B, C, OR D, SEE FIGURE 11-17.  
NOTE: FORMULA FOR SAFE WORK LOAD FOR HOOKS:

$$T \text{ (TONS)} = D^2 (IN^2).$$



## UTILIZATION OF HEAVY EQUIPMENT

## 12--1. GENERAL

a. This chapter should be used as a general guideline when estimating construction equipment requirements and production. *Production estimates given are based on average conditions, and may vary considerably with actual job site conditions. More detailed information may be found in TM's 5-331 A through E.*

b. Good jobsite management requires constant monitoring of the operation, adjusting resources based on actual production to insure maximum utilization of equipment, and proper sequence and coordination of all related operations.

## 12--2. CONSTRUCTION CLEARING

Crawler tractor clearing production. See table 12--1.

## 12-3. STRIPPING, EXCAVATING, AND HAULING

a. *Equipment Selection and Production.* See table 12--2.

b. *Crawler Tractor/Dozer*

(1) Crawler tractors are the most economical equipment for moving earth for short distances (0 to 300 feet). A medium-sized dozer has a blade capacity of 5.0 cubic yards and will consume approximately 9 gallons of fuel per hour of normal operation.

(2) Dozer production may be maximized by slot dozing, blade-to-blade dozing, downhill dozing, and ripping the soil prior to dozing.

(3) Dozers should be used to push-load towed scrapers by one of the following procedures.

(a) *Backtrack loading.* The dozer pushes the scraper until loaded, backs through the area just cut, positions itself behind the second loader, and repeats the loading cycle.

Table 12-1. Estimates for Area Clearing\*

Production Estimates in Acres per hour			
Equipment	Vegetation Density		
	Light	Medium	Heavy
Medium size dozer w/bull blade	.40	.20	.10
Medium size dozer w/tree dozer blade	2.50	1.25	.77

\* Reference DA PAM 525-6, June 1970.

(b) *Shuttle loading.* After the dozer push-loads the first scraper, another scraper is positioned so the dozer can reverse direction and load the second scraper while traveling in the opposite direction.

(c) *Chain loading.* In long cuts, the dozer push-loads the first scraper, then moves behind and pushes the second scraper which is moving in the same direction and adjacent to the first.

c. *Scraper Production.* Scraper production can be maximized by downhill loading, straddle loading, and ripping the soil prior to loading.

d. *Haul Roads.* All haul roads should be maintained with a grader to lower rolling resistance and insure that all loaded units can leave the cut area as fast as possible.

## 12-4. LIFTING AND LOADING

a. *Power Shovel and Dragline Production.* See table 12-3.

**Production Estimates in Bank Cubic Yards Per Hour**

Distance	EQUIPMENT		
	Dozer Med, Ft	R/T Tractor Scraper - 18 Cu Yd	Scraper- 24 Cu Yd
15 ft	1600		
30 ft	870		
50 ft	512	259	345
75 ft	350	288	374
100 ft	263	288	374
150 ft	175	240	354
300 ft	87	183	336
500 ft		226	285
1000 ft		181	225
1500 ft		149	182
3000 ft		97	114
1 mi		62	71
2 mi		34	39
3 mi		24	27
5 mi			17

\*AT HAUL DISTANCES GREATER THAN 3000 FT, THE POSSIBILITY OF USING A LOADER AND DUMP TRUCKS SHOULD BE EVALUATED (SEE SECTION 12-4-d). IF LOADERS ARE USED, A DOZER IS NORMALLY REQUIRED TO STOCKPILE MATERIAL.

Table 12-3. Power Shovel and Dragline Production\*

PRODUCTION ESTIMATES IN BANK CUBIC YARDS PER 60 MINUTE HOUR		**	
ATTACHMENT/TYPE MATERIAL	BUCKET SIZE CU. YD.	JOB AND MANAGEMENT FACTORS	
		POOR	GOOD EXCELLENT
MOIST LOAM— LIGHT SANDY CLAY	3/4 2	86 185	124 266
SAND AND GRAVEL	3/4 2	81 172	116 248
GOOD COMMON EARTH	3/4 2	70 156	101 225
CLAY, HARD, TOUGH	3/4 2	57 138	83 199
CLAY, WET, STICKY	3/4 2	36 96	53 139
ROCK, WELL BLASTED	3/4 2	49 120	71 173
ROCK, POORLY BLASTED	3/4 2	26 83	36 120
DRAGLINE			
MOIST LOAM— LIGHT SANDY CLAY	3/4 2	68 138	98 199
SAND AND GRAVEL	3/4 2	65 133	94 191
GOOD COMMON EARTH	3/4 2	55 120	79 173
CLAY, HARD, TOUGH	3/4 2	47 101	68 146
CLAY, WET, STICKY	3/4 2	29 75	41 109

\*REF: TM 5-331-8, May 1968 AND PSCA TECHNICAL BULLETIN NO. 1

\*\*BASED ON SUITABLE DEPTH OF CUT FOR MAXIMUM EFFECT AND A  
MINIMUM SHOVEL CUT OF 30"

Production Estimates In Loose Cubic Yards Per 60--Minute Hour												
SAE Rated Bucket Capacities	Cycle time in seconds											
	20	30	40	50	60	80	100	120	140	160	180	200
1½ cu yd	270	180	135	108	90	67	54	45	38	34	30	27
2½ cu yd	450	300	225	180	150	112	90	75	64	56	50	45
5 cu yd	900	600	450	360	300	225	180	150	128	112	100	90

Table 12-5. Soil Conversion Factors (Estimated)

Soil Type	Initial Soil Condition	Converted to:		
		In Place	Loose	Compacted
Sand	In Place		1.11	.95
	Loose	.90		.86
	Compacted	1.05	1.17	
Loam	In Place		1.25	.90
	Loose	.80		.72
	Compacted	1.11	1.39	
Clay	In Place		1.43	.90
	Loose	.70		.63
	Compacted	1.11	1.59	
Rock (blasted)	In Place		1.50	1.30
	Loose	.67		.87
	Compacted	.77	1.15	

d. *Estimating Dump Truck Requirements.* The following formula is used to make a preliminary estimate of the number of trucks required to keep loading equipment in operation at maximum capacity.

$$N = \frac{1 + \text{travel time (min)}}{\text{loading time (min)}}$$

N = number of trucks required

(1) The travel time is the time that is required for a hauling unit to complete one cycle of operation and may be determined by actual measurement or by estimation. The time required for a loaded dump truck to pull away from the loading equipment, travel to the site where the material is required, unload, return to the loading unit, and be reloaded is one complete cycle.

(2) The loading time is the time required for the loading equipment to actually load the truck. This is determined by dividing the truck size (in cubic yards) into the loading unit production (in cubic yards per hour) to get loads per hour. Divide loads per hour into 60 to obtain loading time in minutes.

(3) Example: How many 5-cubic-yard trucks would be required to haul 150 cubic yards per hour with a travel cycle time of 30 minutes?

Solution:

$$\frac{150 \text{ cu yds/hour}}{5 \text{ cu yds/load}} = 30 \text{ loads per hour}$$

$$\frac{60}{30} = 2 \text{ minutes loading time}$$

$$N = 1 + \frac{\text{travel time (min)}}{\text{loading time (min)}} = 1 + \frac{30}{2} = 1 + 15 = 16$$

$$N = 16 \text{ trucks}$$

$$N = 1 + \frac{\text{travel time (min)}}{\text{loading time (min)}} = 1 + \frac{30}{2} = 1 + 15 = 16$$

$$N = 16 \text{ trucks}$$

Table 12--6. *Production Capabilities of Graders*

Operation	Rate Per Hour	Unit	Conditions
Ditching	250	Cu Yd	"V" ditching, easy digging
	150	Cu Yd	"V" ditching, medium digging
	85	Cu Yd	"V" ditching, hard digging
Grading	.2	Mile	Digging side ditches and shaping crown, 4 round trips required
Subgrade Preparation	400	Sq Yd	Scarify and shape
Base Course Preparation	200 450	Cu Yd Cu Yd	Spreading material Shaping surface
Surface Treatment	150	Sq Yd	Mixing in place 2 inches of bituminous material

*NOTE:* For working distances up to 1000 feet, graders should back up to beginning of project. For longer distances, turn grader around.

*b. Steps in hasty road construction:*

(1) *Marking cut.* Place right front wheel in line with ditch stakes. Set mold board at outside of right front wheel and make a 3 to 4 inch cut along stakes.

(2) *Ditching cut.* Place right front wheel in marking cut. Adjust mold board so leading edge is in line with and behind right front wheel. Make cuts as deep as possible.

(3) *Moving windrow.* Angle mold board and move windrow from ditch cut to center of road.

(4) *Level windrow.* Make road surface and crown.

(5) *Slope.* Slope banks to prevent erosion.

(6) *Police.* Clean and clear ditches.



## 12-6. COMPACTION

- a. *Selection of Compacting Equipment.* The type of soil to be compacted generally governs the type of compactor to be used. For compaction purposes, soils may be divided into two major types; (1) cohesionless, or granular soils, and (2) cohesive soils. Granular soils generally limit the compactors to pneumatic-tired, vibratory, or (rarely) smooth drum compactors. Cohesive soils generally require a footed type compactor.
- b. *Production Capabilities of Sheepfoot Rollers.* See table 12-7.
- c. *Limitations.* A compaction test strip is necessary to determine the depth of lift and the required number of passes. Compactor production may limit cut and fill operations, and should be determined prior to calculating haul unit requirements.

Table 12-7. *Compacting Fill—Sheepfoot Roller*

Production Estimates in Cubic Yards Per Hour				
Equipment	Number of passes			
	5	7	9	10
Sheepfoot roller	880	628	488	440

## 12-7. PRODUCTION AND JOB DURATION ESTIMATION

General estimates of production for engineer construction equipment may be obtained in the following manner:

- a. Select an efficiency factor (E) from table 12-8.

	Type Tractor	Working Hours	Efficiency Factor
Day Operation	Track	50 min/hr	0.83
	Wheel	45 min/hr	0.75
Night Operation	Track	45 min/hr	0.75
	Wheel	40 min/hr	0.67

- b. Estimate the cycle time for the operation in question. Cycle time is a combination of fixed time and variable time. Fixed time is the time required for positioning, loading, and unloading, and is best determined by actual measurement. Variable time is normally the hauling or travel time. Travel time may be calculated by the following equation:

$$\text{Dozer Travel time (min)} = \frac{\text{travel distance (ft)}}{\text{speed (mph)} \times 88}$$

Round trip distance must be used to determine travel time both ways. Variable time plus fixed time would equal cycle time.

- c. Determine the equipment capacity.  
 d. If necessary, convert the equipment capacity to bank cubic yards (See table 12--5).  
 e. Estimate hourly production (P) by the following formula. (Scraper Production)

$$P = \frac{\text{capacity} \times 60 \text{ min/hr} \times E \text{ (eff factor)}}{\text{cycle time (min)}}$$

- f. Estimate time required by the following formula:

$$\text{Time (hours)} = \frac{\text{total job requirement in machine-hours}}{P \times N}$$

N = Number of like equipment units used.

P = Hourly production for one unit.

## CHAPTER 13

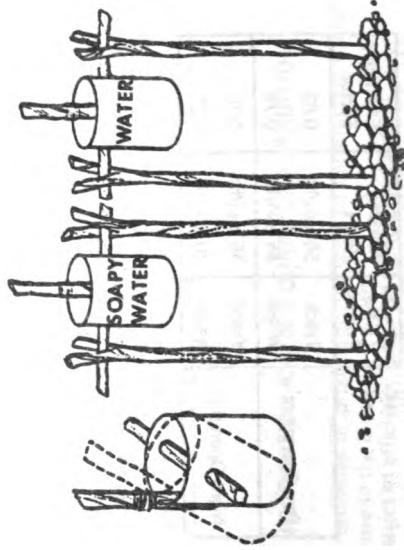
### FIELD SANITATION

#### 13-1. SANITATION FACILITIES

For details on field sanitation see FM 21-10.

#### 13-2. WASHING FACILITIES

- a. Hand-washing devices should be set up near latrines and kitchens. See figure 13-1.



- b. Showers should be set up whenever possible for personal hygiene and morale. See figure 13-2.

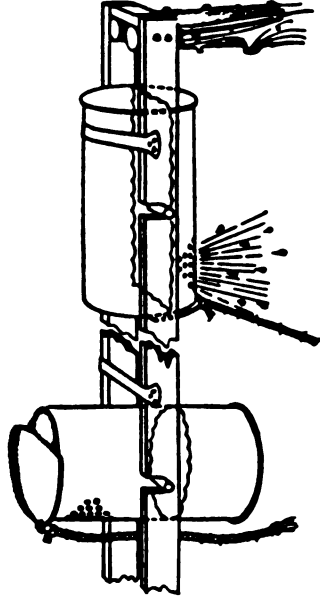


Figure 13-2. Shower unit, using metal drums.

### 13-3. WASTE DISPOSAL

a. *Latrines.*

- (1) Size should be adequate to take care of at least 8 percent of the unit at once. Sixteen feet of straddle trench in four-foot sections, or two deep pit latrines with four-hole latrine boxes, is adequate for a 100-man unit.
- (2) Locate at least 100 meters from kitchen, outside the cantonment area but inside the perimeter, and convenient to tents.
- (3) See figures 13-3, 13-4, and 13-5.

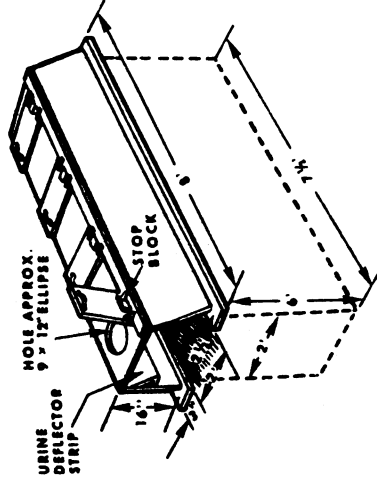
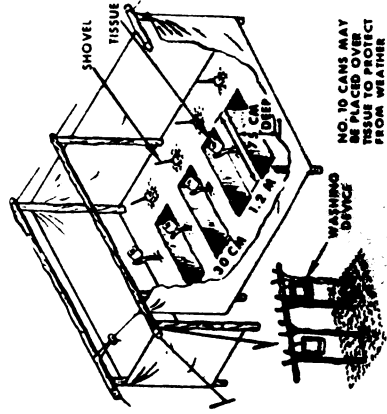
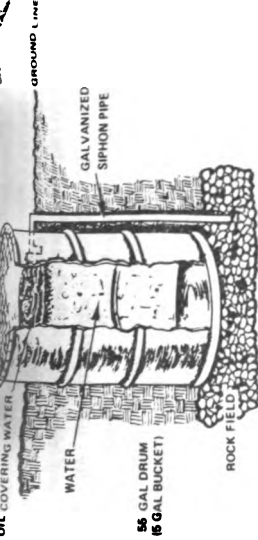


Figure 13-3. Box latrine for 50 men.





**NOTE: USE A SQUIRT CAN DAILY TO SPRAY OIL ON CATCHSCREEN AND AROUND DRUM TO KEEP FLIES AND OTHER INSECTS FROM GATHERING. OIL WILL CURTAIL ANY BAD ODORS.**

*Figure 13-5. Urinoid*

(4) Police the latrines properly and maintain a good fly--control program in the entire camp area to prevent fly breeding and to reduce odors.

(a) Keep the lids to the latrines seats closed and all cracks sealed.

(b) Scrub the latrine seats and boxes with soap and water daily.

(c) Spray the inside of the shelters with a residual insecticide twice weekly. If a fly problem exists, also spray the pit contents and the interior of the boxes twice weekly with a residual insecticide. Using lime in the pits or burning out the pit contents, except in burn--out, is not effective for fly or odor control. Therefore, these methods are not recommended.

(5) At such time as a latrine pit becomes filled with wastes to a point 1 foot from the surface or is to be abandoned, remove the latrine box and close it as follows:

(a) Using an approved residual insecticide, spray the pit contents, the side walls, and the ground surface extending 2 feet from the side walls.

(b) Fill the pit to the ground level with successive 3--inch layers of earth, packing each layer down before adding the next one; then mound the pit over with at least 1 foot of dirt and spray it again with insecticide. This prevents any fly pupa, which may hatch in the closed latrine, from getting out.

(c) Place a rectangular sign on top of the mound. The sign must indicate the type of pit and the date closed as well as the unit designation in non-operational areas.

(6) When high water tables preclude the use of pit latrines, burn-out latrines may be used. Half of a 55-gallon drum or barrel is installed under each hole in the latrine box (fig. 13-6). The drum is removed daily, fuel oil is added and the contents are burned to a dry ash. An inch of diesel fuel is added for insect control before replacing the drum in the latrine box.

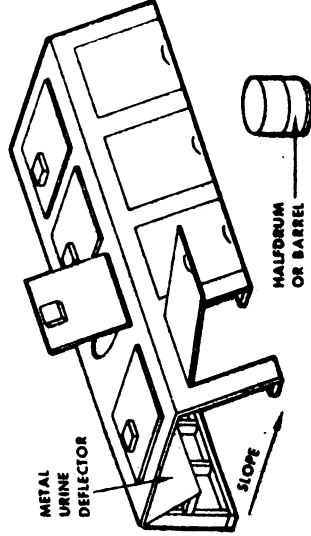


Figure 13-6. Burn-out latrine.

#### b. Garbage Pits.

- (1) Size should be at least 4 feet square and 4 feet deep.
- (2) Locate as far from kitchen as possible, outside camp area if practical.

(4) Liquid kitchen wastes should never be dumped into garbage pits as this precludes effective burning out and shortens utilization for the pit.

c. *Soakage Pits.* Liquid Kitchen wastes should be disposed of in soakage pits. These should be located in the kitchen area. The soakage pit may be constructed the same as the urinoil (fig. 13-5) except that a grease trap must be provided (fig. 13-7) and drainage provided to prevent surface runoff from filling up the pit. In constructing the pit, omit pipes and have drainage from grease pipe drain into pit.

#### PREFORATED WOODEN BOX WITH GRASS FOR STRAINING

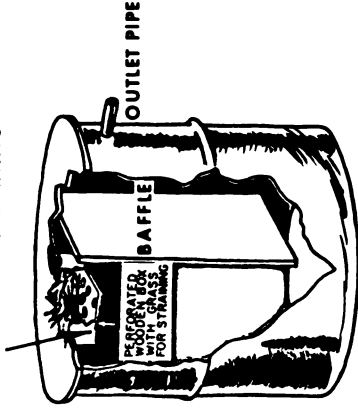


Figure 13-7. Baffle grease trap (barrel type).



## CHAPTER 14

## RECONNAISSANCE

## 14-1. ROUTE RECONNAISSANCE

*a. Definition.* Route reconnaissance provides information to aid in route selection for the movement of troops, equipment, and supplies. It is governed by the same fundamentals that apply to all reconnaissance and is made on the ground, but should be supplemented by air reconnaissance when practicable. Information sought in this type of reconnaissance includes:

- (1) Nature of terrain.
- (2) Existing roads and their characteristics, including loadbearing capabilities. See TM 5-330 for more detailed information.
- (3) Obstructions.
- (4) Bridges and other stream crossing means
- (5) Tunnels.

*b. Mission.* Route reconnaissance must consider the mission of the parent unit. Reconnaissance factors include the weight, width, and height of the vehicles that will be used, the classification of these vehicles, the approximate number of each class to be moved per hour, and the approximate length of time the route will be used.

*c. Report.* A reconnaissance report should be accurate, concise, and clear. The preferred method of preparation is in simplified map form or overlay (fig. 14-1), using symbols (table 14-1) to show the limiting features. A route reconnaissance report is accompanied by an engineer reconnaissance report form, a road reconnaissance report, and bridge, tunnel, ferry, and ford reconnaissance reports as needed. (Fig. 14-2). Military sketches of limiting features, local maps, and photographs of significant factors (terrain, roads, tunnels, bridges, ferries, fords, and so forth) support



Table 14-1. Overlay Symbols

## SYMBOLS FOR USE IN THE RECONNAISSANCE REPORT



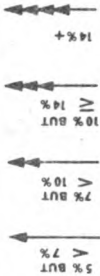
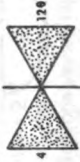
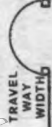
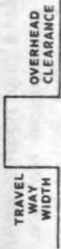
SYMBOL	DESCRIPTION & CRITERIA
	<p>SHARP CURVE: (OB) ANY RADIUS LESS THAN OR EQUAL TO 30 METERS; HOWEVER, ANY CURVE GREATER THAN 30 METERS, BUT LESS THAN 45 METERS IS REPORTABLE.</p>
	<p>SERIES OF SHARP CURVES: THE FIGURE TO THE LEFT INDICATES THE NUMBER OF CURVES; THAT TO THE RIGHT, THE MINIMUM RADIUS OF CURVATURE IN METERS.</p>
	<p>STEEP GRADES: (OB) ANY GRADE 7% OR HIGHER. ACTUAL % OF GRADE WILL BE SHOWN. ARROWS ALWAYS POINT UPHILL, AND LENGTH OF ARROW REPRESENTS LENGTH OF GRADE IF MAP SCALE PERMITS.</p>
	<p>CONSTRICTION: (OB) ANY REDUCTION IN THE TRAVELED WAY BELOW THE STANDARDS OF TABLE 14-2. THE FIGURE TO THE LEFT INDICATES THE WIDTH OF THE CONSTRICTION; THAT TO THE RIGHT, THE TOTAL CONSTRICTED LENGTH, BOTH IN METERS.</p>
<p>ARCH TYPE</p>  <p>RECTANGULAR</p> 	<p>UNDERPASSES: SHOW SHAPE OF STRUCTURE (OB) WHEN OVERHEAD CLEARANCE IS LESS THAN 4.30 M OR WHEN THE TRAVELED WAY IS BELOW THE STANDARDS OF TABLE 14-2. SEE FIG 14-2, NOTE 4.</p>

Table 14-1. Overlay Symbols (Con't)




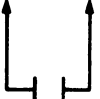
SYMBOL	DESCRIPTION & CRITERIA
<div style="display: flex; flex-direction: column; align-items: center;"> <div style="display: flex; flex-direction: column; align-items: center;"> <div style="border: 1px solid black; padding: 2px; margin-bottom: 5px;">OVERHEAD CLEARANCE</div> <div style="border: 1px solid black; padding: 2px; margin-bottom: 5px;">SERIAL NUMBER (NOTE 1)</div> <div style="border: 1px solid black; padding: 2px;">LENGTH</div> </div> <div style="display: flex; align-items: center; margin-top: 10px;"> <div style="text-align: center; margin-right: 10px;">  </div> <div style="text-align: center;"> <div style="border-bottom: 1px dashed black; width: 100px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; width: 100px;"></div> </div> </div> </div>	<p>TUNNEL: (INCLUDES MANMADE SHOWERSHEDS). SHOW SHAPE OF STRUCTURE. (OB) WHEN OVERHEAD CLEARANCE IS LESS THAN 4.30 M OR WHEN THE TRAVELED WAY IS BELOW THE STANDARDS OF TABLE 14-2 SEE FIG 14-2, NOTE 4.</p>
<div style="display: flex; justify-content: space-around; align-items: center;">    </div>	<p>BYPASSES: ARE LOCAL ALTERNATE ROUTES WHICH ENABLE TRAFFIC TO AVOID AN OBSTRUCTION. BYPASSES ARE CLASSIFIED AS EASY, DIFFICULT, OR IMPOSSIBLE. EACH TYPE BYPASS IS REPRESENTED SYMBOLICALLY ON THE LINE EXTENDING FROM THE SYMBOL TO THE MAP LOCATION AND DEFINED AS FOLLOWS:</p> <p>BYPASSES EASY: THE OBSTACLE CAN BE CROSSED WITHIN THE IMMEDIATE VICINITY BY A US 2.5 TON TRUCK (OR NATO EQUIVALENT) WITHOUT WORK TO IMPROVE THE BYPASS.</p> <p>BYPASS DIFFICULT: THE OBSTACLE CAN BE CROSSED WITHIN THE IMMEDIATE VICINITY, BUT SOME WORK WILL BE NECESSARY TO PREPARE THE BYPASS.</p> <p>BYPASS IMPOSSIBLE: THE OBSTACLE CAN ONLY BE CROSSED BY ONE OF THE FOLLOWING METHODS.</p> <ol style="list-style-type: none"> <li>(1) REPAIR OF ITEM: I.E., BRIDGE</li> <li>(2) NEW CONSTRUCTION</li> <li>(3) DETOUR USING AN ALTERNATE ROUTE WHICH CROSSES THE OBSTACLE SOME DISTANCE AWAY.</li> </ol>

Table 14--1. Overlay Symbols (Con't)


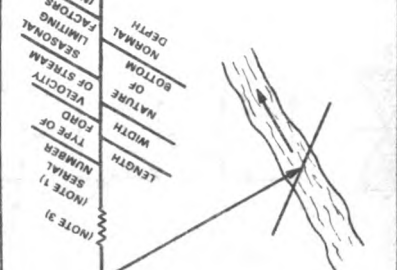

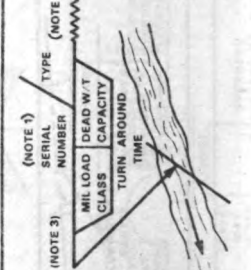

SYMBOL	DESCRIPTION & CRITERIA
	<p>RAILROAD (RR) LEVEL GRADE CROSSING: PASSING TRAINS WILL INTERRUPT TRAFFIC FLOW. THE FIGURE INDICATES OVERHEAD CLEARANCES.</p>
	<p>FORD: ALL FORDS ARE CONSIDERED AS OBSTRUCTION (OB) TO TRAFFIC. TRAFFICABILITY CONDITIONS SHOWN IN TABLE 14-8. INDICATE CONDITIONS ON BOTH APPROACHES. SEE FIGURE 14-2, NOTE 3</p> <p>TYPE OF FORD: V — VEHICULAR    P — PEDESTRIAN</p> <p>SEASONAL LIMITING FACTORS: X — NO SEASONAL LIMITATION EXCEPT FOR DURATION SUDDEN FLOODING. Y — SIGNIFICANT SEASONAL LIMITATIONS.</p> <p>APPROACH CONDITIONS   — DIFFICULT    — EASY</p> <p>NATURE OF BOTTOM: M — MUD    C — CLAY    S — SAND G — GRAVEL    R — ROCK    P — ARTIFICIAL PAVING</p>
	<p>FERRY: ALL FERRIES ARE CONSIDERED AS OBSTRUCTIONS (OB) TO TRAFFIC.</p> <p>APPROACH CONDITIONS   — DIFFICULT    — EASY</p> <p>TYPE OF FERRY: V — VEHICULAR FERRY    P — PEDESTRIAN FERRY</p>

Table 14-1. Overlay Symbols (Con't)


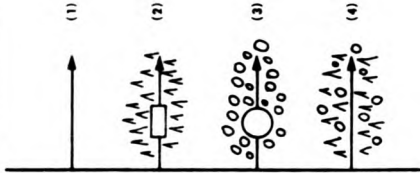



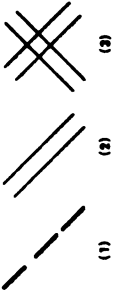

SYMBOL	DESCRIPTION & CRITERIA
(495) 	ROUTE DESIGNATION: CIVIL OR MILITARY ROUTE DESIGNATION. WRITTEN IN PARENTHESES ALONG ROUTE.
 <p>(1) POSSIBLE TURN OFF</p> <p>(2) TRACKED VEHICLE TURN OFF WITH CONIFEROUS CONCEALMENT.</p> <p>(3) WHEELED VEHICLE TURN OFF WITH DECIDUOUS CONCEALMENT.</p> <p>(4) POSSIBLE TURN OFF IN MIXED CONCEALMENT.</p> <p>NOTE: RECORD DISTANCE ON STEM OF ARROWS WHEN OFF ROUTE MOVEMENT IS LESS THAN ONE KM.</p>	<p>OFF-ROUTE MOVEMENT (TURN OFF'S) &amp; CONCEALMENT (ARROWS POINT TO LEFT OR RIGHT OF ROAD WHERE TURN OFF EXISTS):</p> <p>(1) POSSIBLE TURN OFF</p> <p>(2) TRACKED VEHICLE TURN OFF WITH CONIFEROUS CONCEALMENT.</p> <p>(3) WHEELED VEHICLE TURN OFF WITH DECIDUOUS CONCEALMENT.</p> <p>(4) POSSIBLE TURN OFF IN MIXED CONCEALMENT.</p> <p>NOTE: RECORD DISTANCE ON STEM OF ARROWS WHEN OFF ROUTE MOVEMENT IS LESS THAN ONE KM.</p>

Table 14-1. Overlay Symbols (Con't)

SYMBOL	DESCRIPTION & CRITERIA
	LIMITS OF SECTOR: LIMITS OF RECONNOITERED SECTOR OR OF ROUTE HAVING THE SAME ROAD CLASSIFICATION FORMULA.
	CULVERT: REGARDLESS OF TYPE, LENGTH, SIZE, OR NUMBER OF PIPES IN THE SYSTEM.
	CRITICAL POINTS: ARE USED AS NUMBERED KEYS TO DESCRIBE IN DETAIL ON ATTACHED RECONNAISSANCE FORMS OR DOCUMENTS, THOSE FEATURES THAT CANNOT BE ADEQUATELY COVERED BY OTHER RECONNAISSANCE SYMBOLS ON THE OVERLAY.
	OBSTACLES (ROAD BLOCKS, CRATERS, BLOWN BRIDGES, LANDSIDES, ETC.): 1. PROPOSED OBSTACLE 2. PREPARED BUT PASSABLE OBSTACLE 3. COMPLETE OBSTACLES
	UNKNOWN OR DOUBTFUL INFORMATION: USED IN ALL SYMBOLS WHERE INFORMATION IS NOT KNOWN, OR DOUBTFUL.

# ENGINEER RESOURCE SYMBOLS



SAWMILL



ELECTRICAL  
SUPPLY  
EQUIPMENT



LUMBER YARD



WATER POINT  
(MILITARY)



AGGREGATE  
(INCLUDING  
GRAVEL, SLAG) ETC.



FORESTRY  
EQUIPMENT



SAND



PAINT



IRON & STEEL  
STOCK



GYP SUM  
& LIME  
PRODUCTS



WIRE STOCK



CEMENT  
CONCRETE  
PRODUCTS



MOBILE HEAVY  
CONSTRUCTION  
EQUIPMENT



BRICK &  
OTHER CLAY  
PRODUCTS



QUARRING  
EQUIPMENT



FACTORIES



POWERED  
HAND TOOLS



ASPHALT &  
BITUMINOUS  
STOCK

UTILITY (CIVILIAN)



WATER



CORDAGE,  
NETS & YARN



GAS

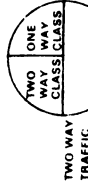
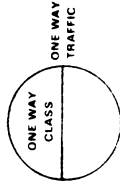
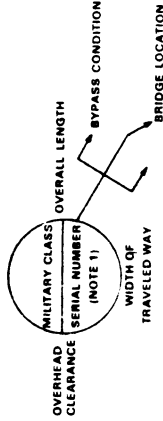


ELECTRIC



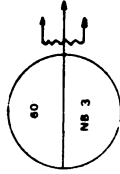
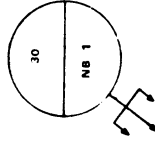
## FULL BRIDGE SYMBOLS

(NOTE 4)



## ABBREVIATED BRIDGE SYMBOLS

(WHEN USED, OVERLAY MUST BE ACCOMPANIED WITH DA FORM 1249 OR DETAILED REPORT.)



ONLY SINGLE FLOW TRAFFIC IS REPRESENTED IN ABBREVIATED BRIDGE SYMBOLS. FOR BRIDGES WITH SEPARATE TRACKED AND WHEELED VEHICLE CLASSIFICATION, ONLY THE LOWER CLASSIFICATION IS SHOWN. IF A BRIDGE HAS MORE THAN ONE CLASSIFICATION, THE CLASSIFICATION NUMBER SHOWN IS ASTERISKED (\*) AND FULL CLASSIFICATION IS SHOWN IN THE ACCOMPANYING REPORT.

NOTE 1.	SERIAL NUMBER	ASSIGNED TO EACH BRIDGE, TUNNEL, FORD AND FERRY.
NOTE 2.	TRAVELED WAY WIDTH	IF SIDEWALKS EXIST AND WILL PERMIT THE PASSAGE OF WIDER VEHICLES, SYMBOLIZE THE SIDEWALKS AND RECORD THE WIDTH AS THE TRAVELED WAY/TOTAL WIDTH.
NOTE 3.	BANK	THE LEFT AND RIGHT BANKS OF A STREAM ARE DETERMINED BY LOOKING IN THE RIGHT DIRECTION OF THE CURRENT DOWNSTREAM.

## BANK

## NOTE 4.

CRITICAL

DIMENSIONS

ANY OVERHEAD CLEARANCE LESS THAN THE STANDARDS OF TABLE 14-2 IS UNDERLINED. ANY WIDTH OF A BRIDGE WHICH IS LESS THAN THE STANDARDS OF TABLE 14-2 IS UNDERLINED. THE TWO WAY CLASS OF ANY TWO LANE BRIDGE IS UNDERLINED IF THE WIDTH OF THE BRIDGE IS LESS THAN THE STANDARDS OF TABLE 14-2. THE WIDTH OF THE TRAVELED WAY OF TUNNELS OR UNDERPASSES WHICH IS LESS THAN THAT OF THE OUTSIDE ROUTE IS UNDERLINED.

- (1) Two grid references.
- (2) Magnetic north arrow.
- (3) Route drawn to scale.
- (4) Title block.
- (5) Route classification formula.
- (6) Length (in kilometers) between well marked points.
- (7) Curves having radii of less than 45 meters or 150 feet.
- (8) Steep grades, with their maximum gradients in percent, and length of any grade of 5 percent or greater.
- (9) Road width of constrictions (bridges, tunnels and so forth), with the widths and lengths of the traveled ways in meters.
- (10) Underpass limitations, with their limiting heights and widths in meters.
- (11) Bridge bypasses, classified as easy, difficult, or impossible.
- (12) Civil or military road numbers, or other designations.
- (13) Feasibility of driving off roads, including shoulders.
- (14) Location of fords, ferries, and tunnels including limiting information.
- (15) Causeways, snowsheds, and galleries which constitute an obstruction to traffic should be included in the route reconnaissance report. Limit the data to clearance and load-carrying capacity. If possible, support the information with photographs or sketches of each structure. Also, include enough descriptive information to permit an evaluation concerning the strengthening or removal of these structures.

e. *Route Classification Formula.* It is a standardized sequence of:

- (1) *Width.* Narrowest width of the route expressed in meters (m) or feet (ft).
- (2) *Route type.* Determined by worst section of the route.
  - (a) *(X) All-weather.* Any road which, with reasonable maintenance, is passable throughout the year to a volume of traffic never appreciably less than its maximum capacity. This type of road has a waterproof surface and is only slightly affected by rain, frost, thaw, or heat. At no time is it closed to traffic due to weather effects other than snow blockage. Examples of this category are concrete, bituminous, brick, or stone.

(b) (Y) *Limited all-weather.* Any road which, with reasonable maintenance, can be kept open in bad weather to a volume of traffic which is considerably less than its normal capacity. This type of road does not have a waterproof surface and is considerably affected by rain, frost, or thaw. Examples of this category are crushed rock or waterbound macadam, gravel, or lightly metalled surface.

(c) (Z) *Fair weather.* A road which becomes quickly impassable in bad weather and which cannot be kept open by normal maintenance. This type of road is seriously affected by rain, frost, or thaw. Examples of this type are natural or stabilized soil, sand or clay, shell, cinders, or disintegrated granite.

(3) *Military route classification.* Normally it is the lowest one-way bridge load classification along the route. If no bridges exist the worst section of the route governs.

(4) *Obstructions (OB).* Any factors which restrict type, amount, or speed of traffic flow, e.g., overhead clearances, traveled way widths, steep gradients, sharp curves, ferries, and fords which may cause obstructions, denoted by (OB) in the route classification formula. Consult tables 14--1 and 14--2 for limiting values.

(5) *Special conditions.* Snow blockage (T) and flooding (W) are used when the condition is regular, recurrent, and serious.

*Example:*

6.7 m Y 30 (OB) (W). Route is 6.7 meters wide, limited all-weather route with a load carrying capacity of class 30. Obstructions do exist and route is subject to flooding.

## 14--2. ROAD RECONNAISSANCE

Road reconnaissance is performed in order to obtain information on road classification, primarily in support of selecting a route, and to report changes to existing maps for dissemination in the theater of operations. Its purpose is to find out the quantity and kinds of loads that a road can accommodate in its present condition. It may also include estimates of the effort necessary to improve and/or maintain a road subjected to specific traffic for a definite

Table 14-2. Critical Dimensions of Route Classification

—ROUTE WIDTHS

TRAFFIC FLOW POSSIBILITIES	WIDTHS FOR WHEELED VEHICLES	WIDTHS FOR TRACKED VEHICLES
SINGLE FLOW	5.50 METERS TO 7 METERS (18 FT TO 23 FT)	6 METERS TO 8 METERS 19 1/2 FT TO 26 FT
DOUBLE FLOW	OVER 7 METERS 23 FT	OVER 8 METERS 26 FT

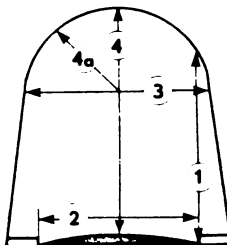
—MINIMUM ROUTE WIDTHS FOR BRIDGES

BRIDGE CLASSIFICATION	MINIMUM WIDTH BETWEEN CURBS	
	ONE LANE METERS	TWO LANE METERS
4-12	2.75 (9'-0")	5.50 (18'-0")
13-30	3.35 (11'-0")	5.50 (18'-0")
31-60	4.00 (13'-2")	7.30 (24'-0")
61-100	4.50 (14'-9")	8.20 (27'-0")

MINIMUM OVERHEAD CLEARANCES FOR BRIDGES

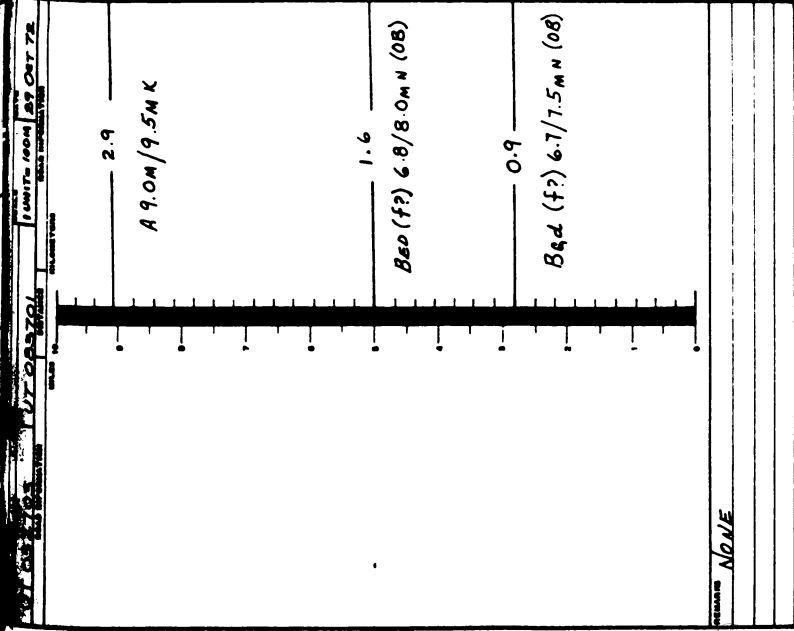
BRIDGE CLASSIFICATION	MINIMUM OVERHEAD CLEARANCE
UP TO 70	4.30 METERS 14 FT 0 IN.
ABOVE 70	4.70 METERS 15 FT 6 IN.

MEASURING WIDTH OF ROADWAY AND HORIZONTAL AND VERTICAL CLEARANCES FOR TUNNELS, UNDERPASSES, AND THROUGH TRUSS BRIDGES



1. MINIMUM OVERHEAD CLEARANCE MEASURED VERTICALLY FROM EDGE OF TRAVELED WAY
2. EFFECTIVE WIDTH OF THE TRAVELED WAY CURB TO CURB
3. HORIZONTAL CLEARANCE IS THE MINIMUM WIDTH MEASURED AT LEAST FOUR FEET ABOVE THE TRAVELED WAY
4. MAXIMUM OVERHEAD CLEARANCE IS THE MINIMUM DISTANCE BETWEEN THE TOP OF THE TRAVELED WAY AND THE LOWER EDGE OF THE OVERHEAD OR ANY OBSTRUCTION BELOW THE OVERHEAD SUCH AS TROLLEY WIRES OR ELECTRIC LIGHT WIRES
- 4a. RISE OF ARCH RADIUS OF CURVED PORTION

ROAD RECONNAISSANCE REPORT				DATE	
For use of this form, see FM 5-36, paragraph 4-1, and the following instructions.				29 OCT 72	
FROM (Name, grade and unit of officer or NCO making reconnaissance)				PROJ (Name, grade and unit of officer or NCO making reconnaissance)	
C0, 20 <sup>th</sup> ENGR BN ATTN: 5-2				LARRY B BRUNER CPT CF	
MAPS				C0, 20 <sup>th</sup> ENGR BN	
SHEET NUMBER OF MAPS				SHEET/TIME GROUP (in sequence)	
5567 - III				2912000Z	
SCALE				TIME	
1:50,000				AMS V T33	
SECTION I - GENERAL ROAD INFORMATION					
ROAD GRID REFERENCE					
TO					
UT052703 UT083701					
B. WIDTH OF ROADWAY (Past or action, specify)					
6.7M - 9.0M					
RECONNAISSANCE					
DATE					
29 OCT 72 1200					
SECTION II - DETAILED ROAD INFORMATION (When circumstances permit more detailed information will be shown in an sketch or on the mileage chart on the reverse side of this form. Standard symbols will be used.)					
A. ROAD MARKING (Civilian or Military number of road)					
VIRGINIA 132					
B. WEATHER DURING RECONNAISSANCE (Include last rainfall, if known)					
CLEAR - TEMP 35°					
LAST RAINFALL - APPROX 17 OCT 72					
C. DRAINAGE (Check one ONLY)					
(1) ADEQUATE DITCHES, CANYONS/CANYONS WITH ADEQUATE CULVERTS IN GOOD CONDITION					
(2) INADEQUATE DITCHES, CANYONS/CANYONS ON CULVERTS. WHEN NOTED ARE LOCATED ON SKETCH. THIS IN POOR CONDITION					
FOUNDATION (Check one ONLY)					
(1) STABILIZED COMPACT MATERIAL OF GOOD QUALITY					
(2) UNSTABLE, LOOSE OR EASILY DISPLACED MATERIAL					
SURFACE DESCRIPTION (Complete items 13a and 13b)					
THE SURFACE IS (Check one ONLY)					
(1) SUMPY, RUTTED OR POTHOLED TO AN EXTENT LIKELY TO REDUCE CONVOY SPEED					
TYPE OF SURFACE (Check one ONLY)					
(1) GRAVEL					
(2) METAL					
(3) NATURAL OR STABILIZED SOIL, SAND, CLAY, SHELLS, SELECTED MATERIAL					
(4) OTHER (Describe)					
D. CONCRETE					
(1) BITUMINOUS (Specify type when known)					
(2) BRICK (Paved)					
(3) STONE (Paved)					
E. CRUSHED ROCK OR CORAL					
SECTION III - OBSTRUCTIONS (List in the column below portions of the following obstructions which affect the traffic capacity of a road.)					
If information of any further nature be ascertained, insert "NOT KNOWN"					
(a) Obstructions (obstructions, less than 14 feet or 4.27 meters, such as landslides, bridges, structural signs and engineering buildings, etc.)					
(b) Reductions in width (obstructions, such as embankments, narrow bridges, embankments, and buildings)					
(c) Curves (less than 100 feet (30 meters) in radius)					
(d) Paved					
SERIAL NUMBER					
PARTICULARS					
GRID REFERENCE					
REMARKS					
1 STEEP GRADE - 8% UPHILL EAST 200 M LONG					
2 SHARP CURVE R = 27M					



U.S. GPO: 1974-546-546/5554

Figure 14-4. Road reconnaissance report (back).

a. *Information Required.*

- (1) Local name of road and/or designation.
- (2) Location of road by map grid reference.
- (3) Obstructions, which include, among other items, underpasses, fords, large tree limbs, craters, projecting buildings, areas subject to inundation, and so forth.
- (4) Bridge locations. (para 14--3).
- (5) Tunnel locations, together with their lengths, widths, and heights. (para 14--5 and table 14--1.)
- (6) Snowshed locations and estimated coverage.

b. *Road Classification Formula.* The road classification formula is expressed in a standardized sequence of a prefix, limiting characteristics at present, width of the traveled way, combined width of the traveled way and the shoulders, road surface material, length, obstructions, and special conditions.

(1) *Prefix.* The formula is prefixed by the letter "A" if there are no limiting characteristics. The letter "B" is the prefix if there are any limiting characteristics.

(2) Limiting characteristics

	<i>Symbol</i>
Curves (radius 30m or less).....	c
Gradients (7% or greater).....	g
Drainage (inadequate).....	d
Foundation (unstable).....	f

Surface Condition (rough)

Chamber or superelevation (excessive) .....  
 An unknown or undetermined characteristic is represented by a question mark following the symbol of the feature to which it refers, e.g., (d?).

(3) *Width.* Width of the traveled way is expressed in meters followed by a slash and the combined width of the traveled way and the shoulders. e.g., 14/16.

(A) *Road surface material.* Road surface material is expressed by a

# Concrete

- kb Bituminous or asphaltic concrete (bituminous plant mix).
- nb Bituminous surface treatment on natural earth, stabilized soil, soil, sand-clay or other select material.
- b Used when type of bituminous construction cannot be determined.
- pb Bituminous surface on paving brick or stone
- rb Bitumen-penetrated macadam, water-bound macadam with superficial, asphalt, or tar cover.
- p Paving brick or stone
- r Waterbound macadam, crushed rock, or coral
- l Gravel or lightly metalated surface
- n Natural earth, stabilized soil, sand-clay, shell, cinders, disintegrated granite, or other select material
- v Various other types not mentioned above (indicate length when this symbol is used).
- (5) *Length.* Length of road (in km) may or may not be shown. If shown place in parentheses, e.g., (7.2 km).
- (6) *Obstructions.* Expressed as (OB) when existing on road, e.g., overhead clearance less than 4.30 m, reduction in the traveled way widths below the standards of table 14-2, gradients of 7 percent or greater, and curves with radii of 30 m (100 ft) or less.
- (7) *Special conditions.* Snow blockage (T) and flooding (W) are used when the condition is regular, recurrent, and serious.

## Example:

Bcgd (f?)s 3.2/4.8 nb (4.3 km) (OB) (T): Road has limits of sharp curves, steep grades, bad drainage, unknown foundation and rough surface; 4.3 km long, and contains obstructions. The road is subject to snow blockage.

c. *Measuring Radii of Curves (fig. 14-5).* A method of determining the radius of a curve is based on the formula—

$$R = \frac{c^2 + m}{8m} \frac{1}{2}$$



where:

$c$  = length of cord

$m$  = perpendicular distance from center of cord to centerline (  $\mathcal{C}$  ) of road

$R$  = radius of circle

By fixing  $m$  at any convenient distance, such as 2 meters, the formula becomes—

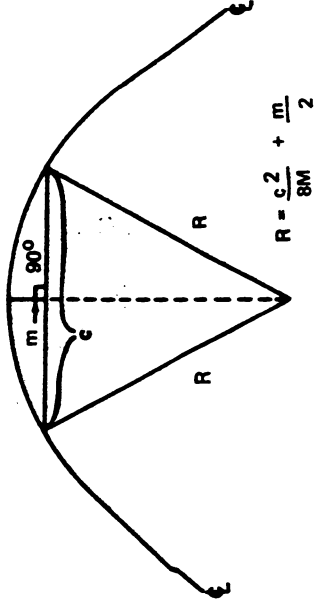
$$R = \frac{c^2}{16} + 1,$$

*Note.* Convert  $R$ ,  $c$ , and  $m$  to like units, either feet or meters, before making computations.

In applying the formula,  $m$  is measured from the centerline of the curve toward the estimated center of the circle and then  $c$  is measured perpendicularly to  $m$  making sure that  $c$  is centered on  $m$ . If  $c$  is measured at 16 meters,  $R = 17$  meters.

d. *Determining road gradient.*

$$\frac{\text{Vertical distance}}{\text{Horizontal distance}} \times 100 = \% \text{ of slope}$$

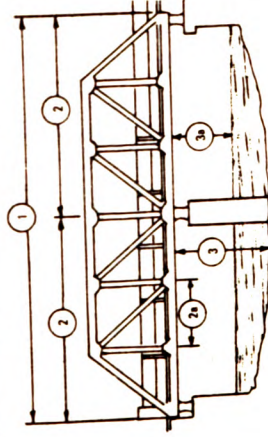


The limiting features of bridges are of basic importance to the selection of a route for normal troop movements. See tables 14-3 and 14-4.

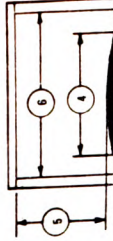
Table 14-3. General Dimension Data Required for Each of the Seven Basic Types of Bridges

NUMBER ON FIGURE	DIMENSIONS DATA	BASIC TYPE OF BRIDGE						SUSPEN- SION
		SIMPLE STRINGER	SLAB	BEAM	TRUSS	GIRDER	ARCH	
1	OVERALL LENGTH	X	X	X	X	X	X	X
2	NUMBER OF SPANS	X	X	X	X	X	X	X
2A	LENGTH OF SPANS	X	X	X	X	X	X	X
3	PANEL LENGTH	...	...	...	...	...	...	X
3A	HEIGHT ABOVE STREAMBED	X	X	X	X	X	X	X
4	HEIGHT ABOVE ESTIMATED NORMAL WATER LEVEL	X	X	X	X	X	X	X
5	TRAVELED WAY WIDTH	X	X	X	X	X	X	X
5	OVERHEAD CLEARANCE	∞	∞	∞	∞	∞	∞	X
6	HORIZONTAL CLEARANCE	X	X	X	X	X	X	X

NOTE: THE LETTER "X" INDICATES THE DIMENSION IS REQUIRED



SIDE VIEW



END SECTION

Table 14-4. Capacity Dimension Data Required for Each of The Seven Basic Types of Bridge

CAPACITY ( ) DIMENSIONS DATA	BASIC TYPES OF BRIDGE										
	SIMPLE STRINGERS					SLAB	T-BEAMS	TRUSS	GIRDER	ARCH	SUSP
	TIMBER		STEEL								
	REC-TANG	LOG	I-BEAM	CHAN- NEL	RAIL						
THICKNESS OF WEARING SURFACE	X					X	X	X	X	X	X
THICKNESS OF FLOORING, DECK, OR	X					X	X	X	X	X	
DEPTH OF FILL AT CROWN											
DISTANCE, C - TO - C, BETWEEN											
T-BEAM, STRINGERS, OR FLOOR											
BEAMS	X	X	X	X	X		X	X	X	X	
NO. OF T-BEAMS OR STRINGERS	X	X	X	X	X		X	X	X	X	
DEPTH OF EACH T-BEAM OR											
STRINGER	X	(2)	X	X	X		X	X	X		X
WIDTH OF EACH T-BEAM OR											
STRINGER	X		(3)	(3)	(3)		X	X	X		
THICKNESS OF WEB OF I-BEAMS,WF-											
BEAMS, CHANNELS, OR RAILS			X	X	X			X	X		
SAG OF CABLE											
NO. OF EACH SIZE OF CABLE											
THICKNESS OF ARCH RING											X
RISE OF ARCH											X
DIAMETER OF EACH SIZE OF CABLE											
DEPTH OF PLATE GIRDER										X	
WIDTH OF FLANGE PLATES										X	
THICKNESS OF FLANGE PLATES										X	
NO. OF FLANGE PLATES										X	
DEPTH OF FLANGE ANGLE										X	
WIDTH OF FLANGE ANGLE										X	
THICKNESS OF FLANGE ANGLE										X	
DEPTH OF WEB PLATE										X	
THICKNESS OF WEB PLATE										X	
AVERAGE THICKNESS OF FLANGE			X								

NOTE: "X" INDICATES REQUIRED DIMENSION.

1. CAPACITY IS COMPUTED BY THE USE OF FORMULAS AND DATA IN BRIDGE MANUALS.

2. DIAMETER.

3. WIDTH OF FLANGE.

Deliberate reconnaissance and engineering reconnaissance are available to make a thorough analysis and classification of the bridge, including necessary repairs or demolition procedures.

The reports include the location of the bridge, bridge number, the classification number, length of the bridge, roadway width, bridge clearance, bypasses, horizontal clearance, underbridge clearance, military loadings, type of span construction material, and length and number of spans (fig. 14-6). Information should be obtained to complete condition of spans (fig. 14-6). Information should be obtained to complete the Bridge Reconnaissance Report Form (DA Form 1249) (figures 14-7 and 14-8). Consult chapter 7 to determine military bridge classification.

c. Bridge bypasses are detours, which are classified as easy, difficult, or impossible. Table 14-1 shows the symbols and requirements for each classification.

#### 14-4. RIVER RECONNAISSANCE

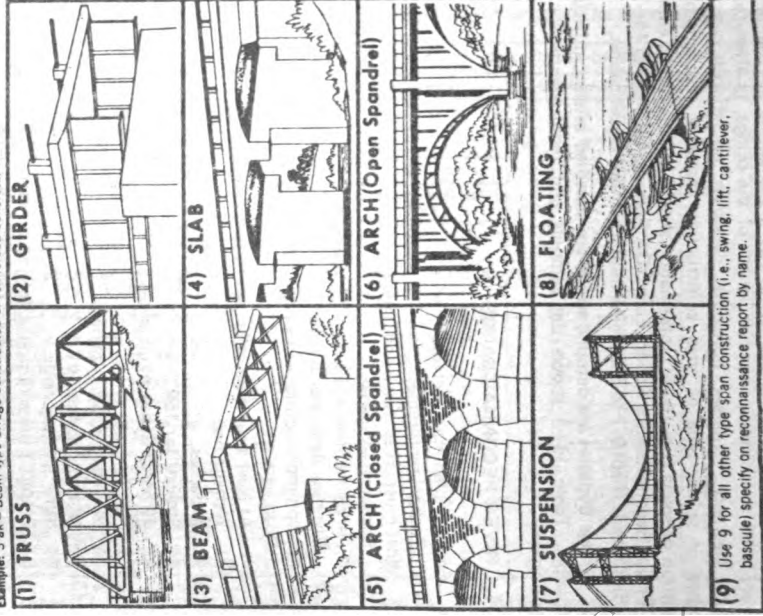
a. Engineer plan must include:

- (1) Tactical requirement.
- What must cross: when and where.
- (2) Resources available.  
i.e., Bridging, men and support equipment.
- (3) Riverline data—(see b below).
- b. Eight common factors for reconnaissance.

- (1) Road nets.
  - (a) At least same class as largest vehicle crossing.
  - (b) Well drained.
- (2) Approaches.
  - (a) Straight for 150'.
  - (b) 10 percent maximum grade.
  - (c) Two lane.
  - (d) All weather, well drained.
- (3) Abutments on banks.
  - (a) Same class as bridge.
  - (b) Protect from scouring, using local material.
  - (c) 30" to 40" high to adjust for approach ramps.

Symbolized on Bridge Reconnaissance Report (DA Form 1249) by Number (Type of Construction) and Letter (Material of Construction).

Example: 3 ak = Beam type bridge constructed of reinforced concrete.



Material Used in Span Construction

Steel or other metal

Concrete

Reinforced Concrete

(1) Spans which are not useable because of damage are symbolized by "x" placed after the dimension of span length.

(2) Spans which are over water are indicated by placing

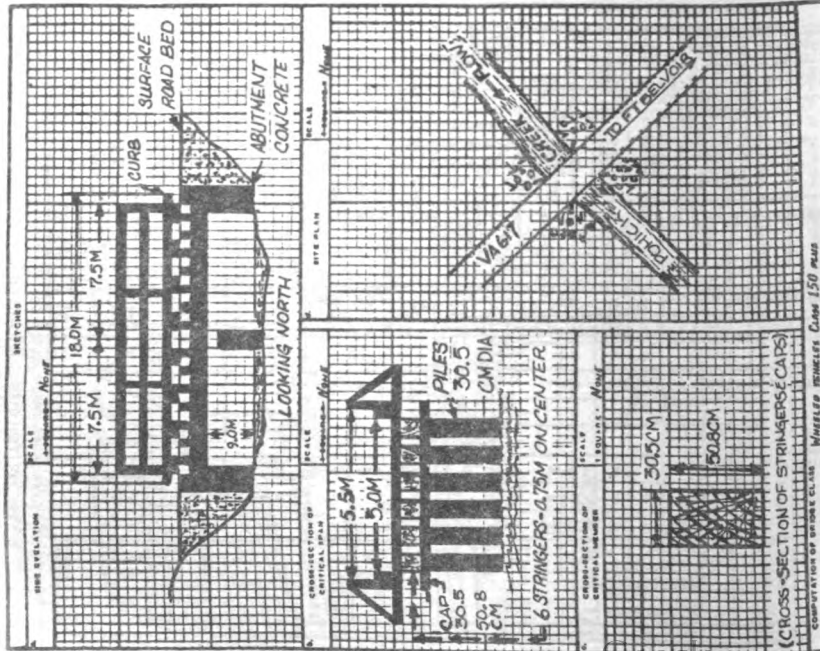
BRIDGE RECONNAISSANCE REPORT (FM 7-2)										DATE 10 JUN 64		SIGNATURE RA ADSITT 2LT CE		
1. Description of bridge (include name)										FROM: Name, grade, and unit of officer or PCN making reconnaissance				
35 <sup>th</sup> ENGR BN ATT 52										RA ADSITT 2LT CE Co A, 35 <sup>th</sup> ENGR BN				
2. County, state and street number of bridge										DATE: 1 mile or more (for highways)				
VIRGINIA ALLANALE 1:2500 SHEET 5561										101530Z				
ESSENTIAL BRIDGE INFORMATION										ADDITIONAL BRIDGE INFORMATION (Add columns as needed) (Military load, clearance, travel, width, height, etc.)				
NO.	LOCATION	CLEARANCE			SPAN			LENGTH AND ORIENTATION	MILITARY LOAD CLASSIFICATION	OVERALL LENGTH	TRAVEL WIDTH	OVERHEAD CLEARANCE	BRIDGE BY-PASS	REMARKS
		HORIZONTAL	VERTICAL	OBSTACLE	NUMBER	TYPE	TYPE							
1	LA072687	55M	2M		1	3	K	4.2M		42M	35M	00	EASY	NONE
2	LA118759	95M	63M		1	4	K	4M		24M	75M	4M	DIFFICULT	NONE
					1	1	2	16M						
					1	4	K	4M						
3	LA163658	140M	23M		5	3	2K	25M		125M	12M	00	IMPOSSIBLE	NONE
4	LA156643	105M	85M		3	6	K	10M		100M	10M	10.5M	IMPOSSIBLE	NONE
					2	2	2	20M						
					3	6	K	10M						

DA Form 1249

PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

GPO 927-548

Figure 14--1. Bridge reconnaissance report form (front).



- (c) *Triangulation*—see number 1, figure 14-9.
- (d) *Scaling from map or aerial photo.*
- (5) *Depth.*

Sounding or expedient methods.

- (6) *Current (tide variation)*—see number 2, figure 14-9.
- (7) *Assembly sites*—desire 100' for each 100' of bridge.
- (8) *Obstructions.*

- (a) *Protect from debris using any expedient methods.*
- (b) *Protect from floating mines using anti-mine boom.*

c. On a reconnaissance, local *populus* may be helpful but keep in mind the enemy could be present.

- d. Other references—TM 5-210.

## 14-5. TUNNEL RECONNAISSANCE

Because tunnels are sometimes used for storage, maintenance, or other purposes, their limitations must be known. (See Table 4-1 and FM 5-36)

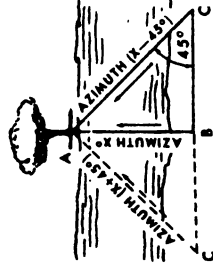
## 14-6. FORD RECONNAISSANCE

- a. The composition of the stream bottom determines its passability.
- b. *Stream Width.*
  - (1) With a compass, determine the azimuth from a point on the near shore close to the water's edge to a point near the water's edge on the far or downstream from the previously marked azimuth. Then another point, either upstream (fig. 14-9).
  - (2) Stretch a string across the stream to the distance across the stream the string. A measuring tape may be used if one long enough is available.

c. *Stream Velocity.* Stream velocity is calculated by measuring a distance along the riverbank, then determining the time it takes a light object to float this measured distance (fig. 14-9). Velocity is computed as follows:



# 1. MEASURING STREAM WIDTH, USING A COMPASS.



1. SELECT PROMINENT OBJECT A (i.e., tree) ON FAR BANK.
2. STAND AT POINT B, OPPOSITE A, AND READ AZIMUTH  $X^\circ$ .
3. MOVE UP OR DOWN STREAM TO A POINT C SO THAT AZIMUTH TO A EQUALS  $X + 45^\circ$  OR  $X - 45^\circ$ .
4. DISTANCE BC THEN EQUALS GAP AB.

## 2. DETERMINING STREAM VELOCITY



DISTANCE AB IS MEASURED  
FLOATING OBJECT IS THROWN INTO STREAM AT C  
TIME REQUIRED FOR FLOATING OBJECT TO FLOAT  
DISTANCE A'B' IS DETERMINED

$$V(\text{FPS}) = \frac{AB (\text{FEET})}{\text{TIME TO FLOAT}} \\ A'B' (\text{SEC})$$

Figure 14-9. Methods of measuring stream width and velocity.

Measured distance (m or ft)  $\div$  Time (sec) = velocity in meters or feet per second

Swiftness of the current and presence of debris affect passability of a ford. Current is recorded as swift (over 1.5 meters per second), moderate (1 to 1.5 meters per second), r slow (less than 1 meter per second).

d. Ford Reconnaissance Report. This report is made on DA Form 1251 (Ford Reconnaissance Report). If required, worksheets may be used

FOOT	1(39")	1(39") (SINGLE FILE) 2(70") (COLUMN OF 2'S)	1:1
TRUCKS AND TRUCK DRAWN ARTILLERY	0.75(30")	3.6(12')	3:1
LIGHT TANK	1(39")	4.2(14')	2:1
MEDIUM TANKS <sup>2</sup>	1.05(42")	4.2(14')	2:1

<sup>2</sup> BASED ON HARD, DRY SURFACE  
2 DEPTHS UP TO 4.3 METERS CAN BE NEGOTIATED WITH DEEP WATER  
FORDING KIT

Table 14--5. *Trafficability of Fords*

#### 14-7. FERRY RECONNAISSANCE

Ferries differ widely in appearance, capacity, propulsion, construction, etc. For information on ferry reconnaissance, see FM 5-36.

#### 14-8. WATER RECONNAISSANCE

a. *Source.* When troops are in combat there is usually no time to search for the best water. Units must take whatever is available and purify as needed. For quantities of water required see table 16-2. Principal sources are: surface water (streams, lakes, and ponds), springs, wells, rain, snow, and ice.

b. *Capacity of Source (Quantity).* Determine the volume of streams, wells or springs, and the dimensions and depths of lakes or ponds, with their rate or outflow. The amount of water that passes a point in one minute is determined as follows:

$$Q = A \times V \times 6.4$$

Where:

Q = Flow in gallons per minute

A = Cross-section area of stream in square feet

V = Flow in ft/min.

6.4 = (7.5 gal of water per cu ft) x (correction factor of 0.85).

- c. *Quality of Water.* Check the color, turbidity, odor, taste, and possible pollution. In a pollution check, examine the drainage area, as much as time permits, for human wastes, industrial wastes, dead fish, or poisoning by enemy action.
- d. *Tests.* Tests are performed by personnel operating water supply points and by medical service personnel.
- e. *Accessibility.* There should be a road system connecting a water supply with the users.
- f. *Proposed Development.* Compute the time, labor, and material necessary to improve the site.
- g. *Data From Local Inhabitants, Local Records, and Soil Surveys.* If a water source is to be used for some time, information must be obtained on seasonal variations and additional sources.
- h. *Standard Symbols.* The above data should be reported on maps using military symbols and signs described in table 14--1, figures 14--12 thru 14--16, and FM 21--30.

## 14--9. ENGINEER RECONNAISSANCE

An engineer reconnaissance is often performed along with a route, or other, reconnaissance. Its primary purpose is to locate engineer materials and to collect and report information on any other factors which might affect engineer operations. The results are usually reported on an overlay similar to the route reconnaissance overlay (fig. 14--1). An Engineer Reconnaissance Report (DA Form 1711--R, figs. 14--10 and 14--11) is prepared with the map overlay.

- a. *Front Side.* Shows sketch, key number, time, and location of item reported.
- b. *Reverse Side.* Gives work estimate of manpower, equipment, and materials to replace, repair, or demolish items reported on the front side of the form. Each work estimate is keyed by number to the appropriate object on the front side of the form. Only those columns which are applicable need

FILE NO. PARTY LEADER (NAME, GRADE, ORGANIZATION) PLACE - HOUR - DATE  
 REPORT NO. 1 W. C. STEVENS, 2LT, CE UT 586708  
 Co A, 21st ENGR BN 130930 MAR 65  
 MAPS QUANTICO, VIRGINIA 1:50,000 SHEET 5561 III  
 DELIVER TO (Organization, Place, Hour and Date)

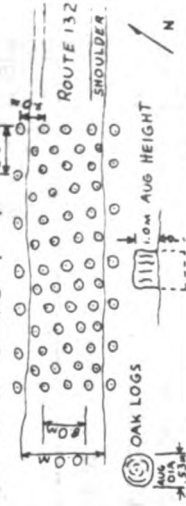
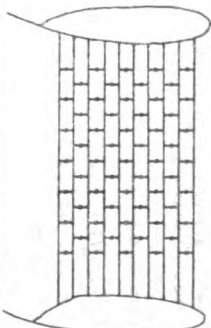
S2, 21st ENGR BN, UT 556461, 131100 MAR 65				ADDITIONAL REMARKS AND SKETCH	
OBJECT	TIME OBSERVED	ESTIMATE?	WORK OBSERVED	UT 058684 - LOG POST OBSTACLE BLOCKING ROUTE 132 (59) LOGS @ 15M C-C ON ALL SIDES. OBSTACLE NOT DEFENDED. BOOBY TRAP CHECK REVEALED NO BOOBY TRAPS. BYPASS ← 130M →	
△	0940	YES			
△	0940	NO		UT 50974 ABANDONED ENEMY EQPT. QUANTITY & TYPE: (2) "ZIPLO" MODEL 200 CRAWLER CRANES (OPERATIONAL) CHECKED FOR BOOBY TRAPS - NONE	
△	1000	NO		UT 761432 EXISTING WATER PURIFICATION PLANT SUPPLYING WATER TO THE CITY OF YUCU. OUTPUT: 50,000 GAL PER DAY.	
TYPED NAME, GRADE AND ORGANIZATION				ENGINEER WORK ESTIMATES ON OTHER SIDE	
W. D. ATKINSON, 2LT, CE				SIGNATURES	
Co A, 21st ENGR BN				William D. Atkinson	
Da Form 1711-2, 1 Jun 61				2LT. CE	
				Edition of 1 May 56 is obsolete.	

Figure 14- 10. Engineer reconnaissance report (front).

ENGINEER WORK ESTIMATE									
LOCATION KEY	DESCRIPTION OF WORK	UNIT REQ'D	HOURS	EQUIPMENT			MATERIALS		
				TYPE	NO.	HOURS	TYPE	UNIT	QUA
$\triangle$ $D = (0.53)(39.37)$ $= 20.8 \text{ INCHES}$ $P = \frac{D^2}{40} = \frac{(20.8)^2}{40}$ $= 10.8 \text{ LBS}$ $11^{\#} \text{ Log} = 649^{\#}$	REMOVE LOG POST FROM ROUTE 132 BY DEMO  PLACEMENT OF CHARGES (DUAL FIRING SYSTEM)	1 SQD	2	DEMO SET #1 D-7 DOZER	1 1	2 2	TNT D- CORD NON ELECT CAP TIME FUSE M-2 FUSE LIGHTER	LBS FT EA FT EA	64 11 2 3 2

RECONNAISSANCE REPORT ON OTHER SIDE

Figure 14--11. Engineer work estimate (back of engineer reconnaissance report).

- (a) *Obstacles.*
- (b) *Engineer materials on site.*
- (c) *Engineer equipment required.*
- (d) *Bivouac areas. Access roads, soil, drainage, size, cover, concealment, fields of fire.*
- (e) *Utilities.*
- (f) *Water points.*
- (g) *Map errors.*
- (h) *Work estimates for construction, repair, or removal of any item encountered on a reconnaissance.*
- (3) *Time observed.*

## 14-10. RECONNAISSANCE OVERLAY SYMBOLS

- a. For frequently used symbols on overlays refer to table 14-1.
- b. *Bridge Symbols.* See figure 14-2 for correct bridge reconnaissance symbols. Consult table 14-2 and chapter 7 for bridge classification procedures.
- c. *Engineer Resource Symbols.* Use the symbols shown in table 14-1 to depict engineer resources. Possible resources are denoted by dashed line symbols.
- d. *Airfield Symbols.* See FM 21-30.
- e. *Minefield Symbols.* See chapter 3.

## 14-11. UNIT DESIGNATIONS

For a complete coverage of military symbols see FM 21-30.

- a. *Branch and Duty Symbols.* Two or more symbols may be combined. For example, armored infantry would combine the symbols for armor and infantry. Some of the more common symbols are shown in figure 14-12.
- b. *Size and Type of Activity Symbols (fig. 14-13).*

AIRBORNE		TRANSPORTATION	
ANTI-AIRCRAFT ARTILLERY		INFANTRY	
ARMOR		MEDICAL	
ARMY AVIATION		MILITARY POLICE	
ARTILLERY		ORDNANCE	
CAVALRY		QUARTERMASTER	
ENGINEER		SIGNAL	

Figure 14-12. Branch and duty symbols.

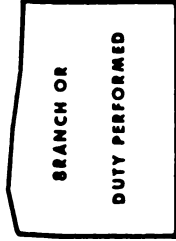
SQUAD	•	ARMY	XXXX
SECTION	••	ARMY GROUP	XXXXXX
PLATOON—DETACHMENT	•••		
COMPANY—			
TROOP—BATTERY			
BATTALION—SQUADRON			
REGIMENT—GROUP			
BRIGADE	X	UNIT HQ	
DIVISION	XX	OBSERVATION OR LISTENING POST	
CORPS	XXX	LOGISTICAL UNIT	
		COMBAT SERVICE SUPPORT	

combinations of symbols to depict numeric units is shown in figure 14-15. Examples of unit designations and basic symbols for engineer units and weapons are found in figures 14-15 and 14-16.

# SIZE OF UNIT

SUB-  
SUB-  
SUB-  
UNIT / SUB-  
UNIT / SUB-  
UNIT

PARENT /  
UNIT /  
HIGHER  
ECHELONS  
OF COMMAND



## ADDITIONAL INFORMATION

Figure 14-14. Unit Designations and Basic Symbols.



16TH ARMORED ENGR. BN. 4TH  
ARMORED DIV.



AVLB PLATOON, BRIDGE CO.,  
31ST ARMORED ENGR. BN.



1ST SQ'D., 2D PLATOON, CO. B.,  
162D ENGR. BN., 5TH INFANTRY  
DIV (MECHANIZED)



581ST ENGR. MAINT CO. (DIRECT  
SUPPORT) attached to  
91st Engr. Bn.

Figure 14-15. Examples of specific engineer unit symbols.



AUTOMATIC INFANTRY WEAPON	↑	MORTAR	↑
AIR DEFENSE MACHINE GUN	↑	ANTI-TANK ROCKET LAUNCHER	↑
ARTILLERY GUN		HOWITZER	↑
RECOILESS RIFLE	↑	ROCKET LAUNCHER	↑
MISSILE OR ROCKET	↑	AIR DEFENSE ROCKET	↑
APC	◇	FULL-TRACKED ARMORED ASSAULT GUN	◇

APPROXIMATE SIZE OF WEAPON IS AS SHOWN BELOW:

LIGHT, BASIC WEAPON SYMBOL	EXAMPLE	↑
MEDIUM, ONE HORIZONTAL BAR	EXAMPLE	↑
HEAVY, TWO HORIZONTAL BARS	EXAMPLE	↑
TANK	LIGHT	↑
	MEDIUM	↑
	HEAVY	↑

Figure 14-16. Weapons symbols.

## 15-1. COMMUNICATIONS EQUIPMENT

See tables 15-1 and 15-2.

## 15-2. EXPEDIENT ANTENNAS

- a. Figures 15-1 thru 15-4 show expedient antennas using commo wire. These may be used with AM or FM radios to extend their range.
- b. In order to determine antenna length in feet, the following formula is used:

$$\frac{1}{4} \text{ wave} = \frac{234}{F} \quad \frac{1}{2} \text{ wave} = \frac{468}{F} \quad \text{Full wave} = \frac{936}{F}$$

Where:

F = Frequency in megahertz

## 15-3. RADIO LOCATION

- a. Locate radio as high as possible.
- b. Location should be away from any metal obstructions.
- c. Avoid placing in a depression or valley, whenever possible.
- d. Avoid locating a radio near electrical power line.

## 15-4. SECURITY

- a. *Communication Security (COMSEC).*
  - (1) Transmission by radiotelephone should be as short and concise as possible consistent with clearness. All personnel must be cautioned that transmissions by radio are subject to enemy intercept and, therefore, are not secure.

Table 15-1. Engineer Communications Equipment Reference Guide- Tactical Radio

NOMENCLATURE	FREQUENCY RANGE MHZ	TACTICAL RADIO SETS			POWER REQUIREMENT	REMARKS
		RANGE IN KILOMETERS	ANTENNA			
AN/PRC 25 SERIES	30-75.95	MAN-PACK OR VEHICULAR OR BOTH	8	3' WHIP (FLEX) 10' WHIP AS-1729	BA-386 BA-4386 VEH. BTRY.	LOW POWER FM. DETENT TUNING. REMOTE. RETRANS. CAPABILITY. PRESETS. BEING REPLACED AN PRC 77 SERIES. REFERENCES TM 11-5820-398-12. TM 11-5820-498-12.
NOTE: AN/PRC-25 SERIES INCLUDES AN/VRC-53 (VEHICULAR) AND AN/GRC-125 (VEHICULAR AND MAN-PACK) AND AN/PRC 25 (MAN-PACK)						
AN/PRC-77 SERIES	30-75.95	MAN-PACK OR VEHICULAR OR BOTH	8	3' WHIP (FLEX) 10' WHIP AS-1729	BA-386 BA-4386 VEH. BTRY.	LOW POWER FM. DETENT TUNING. REMOTE. RETRANS. CAPABILITY. PRESETS. CRYPTO CAPABILITY. REFERENCES TM 11-5820-66-12. TM 11-5820-498-12.
NOTE: AN/PRC-77 SERIES INCLUDES AN/VRC-64 (VEHICULAR) AND AN/GRC-160 (VEHICULAR AND MAN-PACK) AND AN/PRC (MAN-PACK)						
AN/VRC-46	30-75.95	VEHICULAR MTD. RECEIVER/ TRANSMITTER (RT-524)	32	10' CENTER- FED WHIP	24V DC (VEH BTRY) * (1)	MEDIUM POWER FM. DETENT TUNING. REMOTE. RETRANS. CAPABILITY. CRYPTO CAPABILITY * (3) REFERENCES TM 11-5820-401-12
AN/VRC-47	30-75.95	VEHICULAR MTD. RECEIVER TRANSMITTER (RT-524) AND AUX RCVR (R-442)	32	RT-524. 10' CENTER- FED WHIP R-442 OR 6' WHIP	24V DC (VEH BTRY) * (1)	MEDIUM POWER FM. DETENT TUNING. REMOTE. RETRANS. CAPABILITY. CRYPTO CAPABILITY * (3) REFERENCES TM 11-5820-401-12
AN/GRC-106	2.0-29.999	VEHICULAR MTD. AM SSB RCVR/ TRANSMITTER	80	15' WHIP OR DOUBLET	VEHICU LAR-100 AMP KIT * (2)	NO CALIBRATION. NO PRESETS. REMOTE CAPABILITY. REFERENCES TM 11-5820-520-12
AN/GRC-142	2.0-29.999	VEHICULAR MTD. AM SSB RCVR/ TRANSMITTER RADIO TELETYPE SET	80	15' WHIP OR DOUBLET	VEHICU LAR-100 AMP KIT	NO CALIBRATION. NO PRESETS. FULL SECURE CAPABILITY. REFERENCES TM 11-5820-334-12

\* (1) 1 EACH GENERATOR SET, 1.6 KW DC. FOR OPERATION IN A STATIC POSITION. WHEN AC IS AVAILABLE A PP 2953 (UAC DC CONVERTER) IS REQUIRED.

\* (2) WHEN USED IN A STATIC OPERATION A 1.6 KW DC GENERATOR SHOULD BE USED. WHEN AC IS AVAILABLE A PP 2953 (UAC DC CONVERTER) IS REQUIRED. A TSEC KW 7 CAN BE USED FOR TELETYPEWRITER MESSAGE SECURITY.

\* (3) COMMUNICATIONS SECURITY CAPABILITY PROVIDED BY ADDITION OF APPROPRIATE COMSEC EQUIPMENT.

Table 15-2. *Engineer Communications Equipment Reference Guide— Auxiliary Equipment*

		<u>AUXILIARY EQUIPMENT</u>	
<u>ENVIRONMENT</u>	<u>DESCRIPTION</u>	<u>RANGE</u>	<u>REMARKS</u>
GA-39	REMOTING SET, USED WITH FM RADIO SETS	UP TO 2 MI (3.2 KM)	INCREASES FLEXIBILITY OF RADIO SETS. INCREASES SECURITY. RADIO AND ANTENNA CAN BE EXPOSED WHILE OPERATOR IS NOT. REFERENCE TM 11—5820—477—12
PT	GENERAL PURPOSE STATIONARY GROUND PLANE ANTENNA		USED TO EXTEND THE RANGE OF TACTICAL FM RADIO SETS. INCREASES RANGE OF RADIO SETS TO APPROXIMATELY TWICE THE STATED PLANNING RANGE OF THE RADIO SET. RADIATING AND GROUND PLANE ELEMENTS MUST BE OF THE PROPER LENGTH FOR A PARTICULAR OPERATING FREQUENCY. REFERENCE TM 11—5820—348—15
FM	LONG WIRE, END FED DIRECTIONAL ANTENNA		USED WITH TACTICAL FM RADIO SETS. GOOD FOR REDUCING THE ENEMY'S ABILITY TO CONDUCT INTERCEPTION AND JAMMING. CAN EXTEND THE PLANNING RANGE OF RADIO SETS BY DOUBLE OR MORE, DEPENDING UPON THE ANTENNA USED TO RECEIVE/TRANSMIT AT THE DISTANT SITE. REFERENCE TM 11—5820—398—12
<u>WIRE EQUIPMENT</u>			
UPT	SOUND POWERED TELEPHONE IN HAND SET FORM	16 KM	PLANNING RANGE DEPENDS UPON CONDITION OF WIRE (WD-1/TT). NO BATTERIES ARE REQUIRED. INCOMING SIGNAL IS VISUAL AND ADJUSTABLE AUDIBLE. TELEPHONE WEIGHS 2 3/4 LBS, CASE 7/8 LB. REFERENCE TM 11—5805—243—12
UPT	TACTICAL FIELD TELEPHONE	35 KM	PLANNING RANGE DEPENDS UPON CONDITION OF WIRE (WD-1/TT). BATTERIES ARE REQUIRED WHEN OPERATION IS IN LB POSITION. AS IN LOCAL CIRCUIT TO SB. 22/PT. INCOMING SIGNAL IS ADJUSTABLE AUDIBLE. HAS HANDFREE OPERATION CAPABILITY. TELEPHONE WEIGHS APPROXIMATELY 9.5 LBS. REFERENCE TM 11—5805—201—12
PT	LIGHTWEIGHT, MANUAL (MONOCORD) SWITCHBOARD, LOCAL BATTERY (LB) OPERATION.		SWITCHBOARD HAS 12-CIRCUIT CAPABILITY, AND MAY BE EXPANDED BY "STACKING" ADDITIONAL SB-22 S. EACH ADDED SB-22 INCREASES CAPABILITY BY 17 CIRCUITS, SINCE ONLY ONE OPERATOR'S PACK IS NECESSARY. SIGNALING MAY BE AUDIBLE AND VISUAL, OR JUST VISUAL. REFERENCE TM 11—5805—262—12
PT	LIGHT, PORTABLE, EMERGENCY SWITCHBOARD		SWITCHBOARD HAS 6-CIRCUIT CAPABILITY FOR LOCAL BATTERY (LB) TELEPHONE LINES, WITH AN ADDITIONAL "CIRCUIT PLUG" FOR THE OPERATOR'S USE. INCOMING SIGNAL IS VISUAL ONLY. REFERENCE TM 11—5805—294—15

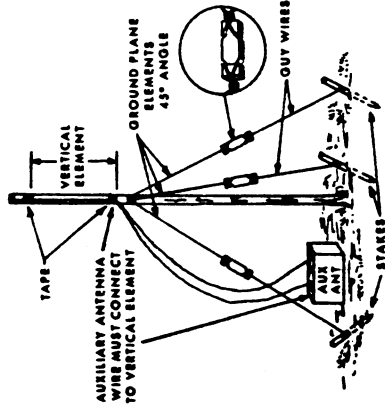
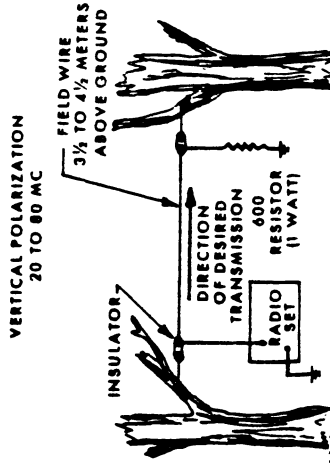


Figure 15-1. Jungle expedient antenna. (FM)



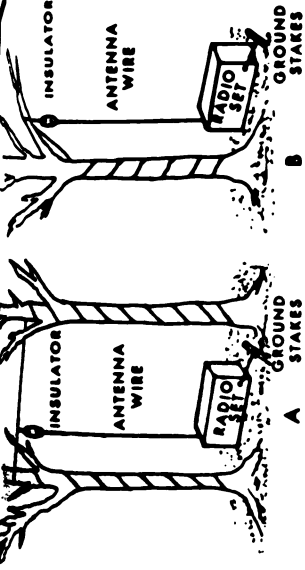


Figure 15 -3. Expedient suspended vertical antennas. (FM)

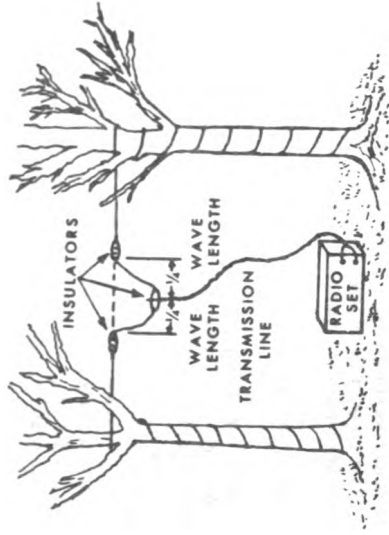


Figure 15 -4. Improvised center fed half-wave antenna. (AM)

## (2) Security checklist for radio operations.

- (a) Is radio silence being violated?
- (b) In unofficial conversation (chatter) being exchanged between operators?
- (c) Are transmissions taking place in a directed net, without permission?
- (d) Is the operator's personal sign being transmitted?
- (e) Are call--signs being compromised by their association with plain language unit designations?
- (f) Is plain language used instead of authorized pro--signs and operating signals?
- (g) Are the operators using unauthorized and incorrect procedures?
- (h) Do unnecessary transmission occur?
- (i) Are calls being transmitted excessively?
- (j) Is the identification of units and individuals being disclosed in transmissions?
- (k) Are transmitting operators sending too fast for receiving operators?
- (l) Is excessive transmitting power being used?
- (m) Are transmitters being tuned with the antenna connected?
- (n) Is excessive time consumed in tuning, testing changing frequency, and adjusting equipment?
- (o) Are authentication requirements and procedures being violated?
- (p) Are call--signs and frequencies changed often?
- (q) Are plain language message cancellations being authenticated?
- (r) Are service messages concerning cryptographic operations always encrypted for transmission?
- (s) Do radio--telephone stations with ciphony capabilities follow the procedures in U.S. Supplement 3?

b. *Electronic Countercounter-measures (ECCM).*

- (1) Authenticate transmissions as prescribed by local instructions.
- (2) Learn to readjust the set to minimize effects of enemy jamming.

## 15-5. STANDARD RADIO TRANSMISSION FORMAT

### CALL

MESSAGE (This pro-- word indicates message requires recording)

PRECEDENCE (Indicates Priority of Call)

TIME (Followed by Date--Time Group)

FROM (Followed by Call Sign)

TO (Followed by Call Sign of Addressee)

BREAK

TEXT (May consists of plain language, code or cipher groups)

BREAK

ENDING (Must include either one of two terminating pro--words: OVER or OUT, but never both in the same transmission)

EXAMPLE: ZULU FOUR CHARLIE ONE SIX -- THIS IS DELTA THREE  
X RAY TWO NINE -- MESSAGE -- PRIORITY -- TIME 181345Z --  
BREAK -- FIGURES 6 STRINGERS NEEDED AT MY LOCATION ASAP  
-- BREAK -- OVER.



## CHAPTER 16

### MISCELLANEOUS FIELD DATA

#### 16-1. WEIGHTS AND SPECIFIC GRAVITIES

Table 16-1 gives weights and specific gravities of materials commonly used in an engineer unit.

#### 16-2. WATER, DISINFECTION AND QUANTITY REQUIREMENTS

##### *a. Water Disinfection.*

(1) *Calcium hypochlorite.* The following procedure is used to purify water in a one-quart canteen with calcium hypochlorite ampules:

(a) Fill the canteen with the cleanest, clearest water available, leaving an air space of an inch or more below the neck of the canteen.

(b) Fill a canteen cup half full of water and add the calcium hypochlorite from one ampule. Stir until dissolved.

(c) Fill the cap of a plastic canteen half full of the solution in the cup and add it to the water in the canteen. Then place the cap on the canteen and shake it thoroughly.

(d) Loosen the cap slightly and invert the canteen, letting the treated water leak onto the threads around the neck of the canteen.

(e) Tighten the cap on the canteen and wait at least 30 min before using the water for any purpose.

(2) *Iodine tablets.* Use 1 tablet per one quart canteen for clear and 2 tablets per one quart canteen for cloudy water. Allow the water to stand for 30 min before using.

Substance	Weight lbs. per cu. ft.	Specific gravity
Asphaltum	81	1.1-1.5
Petroleum, gasoline, & diesel	42	0.66-0.69
Tar, bituminous	75	1.20
Cement, portland, loose	94	2.7-3.2
Cement, portland, set	183	
Clay, damp, plastic	110	
Clay, dry	63	
Earth, dry, loose	76	
Earth, dry, packed	96	
Earth, moist, loose	78	
Earth, moist, packed	96	
Sand gravel, dry, loose	90-105	
Sand gravel, dry, packed	100-120	
Sand gravel, wet	118-120	
Water, 4° C. (max density)	62.428	1.0
Water, ice	56	0.88-0.92
Masonry, ashlar		
Granite, syenite, gneiss	165	2.3-3.0
Limestone, marble	160	2.3-2.8
Sandstone, bluestone	140	2.1-2.4
Masonry, brick		
Pressed brick	140	2.2-2.3
Common brick	120	1.8-2.0
Soft brick	100	1.5-1.7
Masonry, concrete		
Cement, stone, sand	144	2.2-2.4
Masonry, dry rubble		
Granite, syenite, gneiss	130	1.9-2.3
Limestone, marble	125	1.9-2.1
Sandstone, bluestone	110	1.8-1.9
Masonry, mortar, rubble		
Granite, syenite, gneiss	155	2.2-2.8
Limestone, marble	150	2.2-2.6
Sandstone, bluestone	130	2.0-2.2

Table 16-1. *Weights and Specific Gravities (Con't)*

Substance	Weight lbs. per cu. ft.	Specific gravity
Aluminum, cast, hammered	165	2.55-2.75
Copper, cast rolled	558	8.8-9.0
Iron, cast, pig	450	7.2
Lead	710	11.37
Magnesium alloys	112	1.74-1.83
Steel, rolled	490	7.85
Limestone, marble	165	2.5-2.8
Sandstone, bluestone	147	2.2-2.5
Riprap, limestone	80-85	
Riprap, sandstone	90	
Riprap, shale	105	
Glass, common	156	2.4-2.6
Hay and straw (bales)	20	
Paper	58	0.70-1.15
Stone, quarried, piles		
Basalt, granite, gneiss	96	
Greenstone, hornblende	107	
Limestone, marble, quartz	90	
Sandstone	82	
Shale	92	
Excavations in water		
Clay	80	
River mud	90	
Sand or gravel	60	
Sand or gravel and clay	65	
Soil or gravel and clay	70	
Stone riprap	65	
Timber, US, seasoned (moisture content by weight: 15-50%)		
Soft wood	25	.40

uncoagulated, pretreat all water by coagulation and sedimentation followed by sand filtration at reduced rates or by diatomite filtration. Water treated in this way is safe to drink if it has a residual chlorine content of 1 ppm after a 10-minute contact time. In emergencies, disinfect water in individual canteens by following the directions on the bottle of individual water purification tablets unless an increase is directed by the medical officer. Small units may boil their drinking water; this is a sure method. If the lyster bag is used, the following steps must be taken:

- (a) Break 1 ampule of calcium hypochlorite and pour into filled bag. Stir with clean paddle.
  - (b) Disinfect faucets by flushing  $\frac{1}{2}$  cup of water through each faucet.
  - (c) After 10 minutes, residual should exceed 1 ppm. Then add another ampule. Keep bag covered.
  - (d) Water is potable 30 minutes after adding last ampule.
- b. *Daily Water Requirements.* Table 16-2 gives water requirements in gallons per unit consumer per day under various conditions of use.

### 16-3. ELECTRICAL WIRING

- a. The procedures pointed out in this section are to be used only for an estimation of required wire sizes or when no other method is known.
- b. To determine the wire size required for a given load:

- (1) Convert load into amperes required by using

$$\text{Amperes} = \frac{\text{Total watts to be serviced}}{\text{voltage}}$$

$$\text{Amperes} = \frac{\text{Voltage}}{\text{resistance (ohms)}}$$

$$\text{Amperes} = \frac{745.7 \times \text{Horsepower}}{\text{voltage}}$$

- (2) Enter table 16-3 or 16-4 with amperes to be serviced and length of wire required. Determine wire size needed.

- (3) This procedure is to be used when power is to be furnished to a specific load such as one motor or a group of lights. The procedure for wiring a facility or wiring a generator is shown in FM 5-35 and TM 5-766.

Table 16-2. Daily Water Requirements

Unit Consumer	Conditions of Use	Gallons/Day		Remarks
		Mild/Cold	Desert/Jungle	
Man	In Combat:			Eating and drink (3 days) When field rations used Drinking plus cooking and personal hygiene. Minimum for all purposes All purposes (does not include bathing). Waterborne sewage system and bathing.
	Minimum	$\frac{1}{2}$ —1	2—3 <sup>1</sup>	
		2	3—4 <sup>1</sup>	
	Normal	3	6 <sup>2</sup>	
	March	2	5 <sup>2</sup>	
	Temporary camp	5		
Vehicle	Temporary camp	15		
	Semi-permanent camp	30—60		
	Permanent camp	60—100		
Hospital	Level and rolling	$\frac{1}{4}$ — $\frac{1}{2}$		Does not include bathing Includes medical personnel
	Mountainous	$\frac{1}{4}$ —1		
	Drinking and cooking	10/bed		
	Water waterborne sewerage	50/bed		

<sup>1</sup>For unacclimatized personnel or for all personnel when dry bulb readings exceed 105°F, in the jungle.

<sup>2</sup>Maximum consumption factor is dependent upon work performed, solar radiation and other environmental factors.

Table 16--3. Wire Sizes for 110-Volt Single-Phase Circuits

**10--ALUMINUM WIRE  
12--COPPER WIRE**

FOR 110V CIRCUIT DISTANCE TO LOAD IN FEET											
LOAD IN AMPS	50	75	100	125	150	200	250	300	400	500	
15	$\frac{10}{12}$	$\frac{8}{10}$	$\frac{8}{10}$	$\frac{6}{8}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	
20	$\frac{10}{12}$	$\frac{8}{10}$	$\frac{6}{8}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	
25	$\frac{8}{10}$	$\frac{6}{8}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2}{1}$	
30	$\frac{6}{10}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2}{1}$	$\frac{3}{0}$	
40	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{4}{0}$	
50	$\frac{4}{8}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{4}{0}$	$\frac{300}{30}$	
60	$\frac{4}{6}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{4}{0}$	$\frac{250}{30}$	$\frac{400}{250}$	
70	$\frac{4}{6}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{4}{0}$	$\frac{250}{20}$	$\frac{300}{40}$	$\frac{400}{250}$	
80	$\frac{4}{6}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{4}{0}$	$\frac{250}{30}$	$\frac{350}{40}$	$\frac{500}{250}$	
90	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{4}{0}$	$\frac{250}{30}$	$\frac{300}{250}$	$\frac{400}{250}$	$\frac{500}{300}$	
100	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{4}{0}$	$\frac{300}{30}$	$\frac{350}{40}$	$\frac{500}{250}$	$\frac{600}{350}$	

Table 16-4. Wire Sizes for 220-Volt Three-Phase Circuits

**10—ALUMINUM WIRE**  
**12—COPPER WIRE**

FOR 220V CIRCUIT DISTANCE TO LOAD IN FEET										
LOAD IN AMPS.	100	200	300	400	500	600	700	800	900	1000
15	$\frac{12}{12}$	$\frac{8}{10}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{1}{3}$
20	$\frac{10}{12}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{1}{3}$	0	$\frac{0}{2}$
25	$\frac{8}{10}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	0	$\frac{0}{2}$	$\frac{2}{0}$	$\frac{2}{1}$
30	$\frac{6}{10}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	0	$\frac{2}{2}$	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{3}{0}$
40	$\frac{4}{8}$	$\frac{4}{6}$	$\frac{2}{4}$	$\frac{1}{3}$	0	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{3}{0}$	$\frac{4}{2}$	$\frac{4}{2}$
50	$\frac{4}{8}$	$\frac{3}{4}$	$\frac{1}{3}$	0	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{250}{3}$	$\frac{300}{3}$
60	$\frac{4}{6}$	$\frac{2}{4}$	0	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{4}{2}$	$\frac{250}{2}$	$\frac{250}{3}$	$\frac{300}{4}$	$\frac{350}{4}$
70	$\frac{4}{6}$	$\frac{1}{3}$	$\frac{2}{2}$	$\frac{3}{0}$	$\frac{4}{2}$	$\frac{250}{3}$	$\frac{300}{3}$	$\frac{350}{4}$	$\frac{400}{4}$	$\frac{400}{250}$
80	$\frac{4}{6}$	$\frac{1}{3}$	$\frac{2}{1}$	$\frac{3}{0}$	$\frac{4}{2}$	$\frac{250}{3}$	$\frac{350}{4}$	$\frac{400}{4}$	$\frac{500}{250}$	$\frac{500}{300}$
90	$\frac{2}{4}$	0	$\frac{3}{0}$	$\frac{4}{2}$	$\frac{250}{3}$	$\frac{300}{4}$	$\frac{350}{4}$	$\frac{400}{250}$	$\frac{500}{300}$	600

a. *Board Measure, Size and Weight.*

(1) Lumber quantities are expressed in feet, board measure (ft. bd.m.) or in board feet (bd.ft.), or in thousand board feet (M bd.ft.). One board foot is the amount of lumber in a rough-sawed board 1 foot long, 1 foot wide, and 1 inch thick (144 cubic inches) or the equivalent volume in any other shape. The originals or "nominal" dimensions and volumes determine the number of board feet in a given quantity of dressed lumber, regardless of the fact that the process of surfacing or other machining has reduced the actual dimensions and volume. Under American standards, for example, a dressed board designated as 1 inch by 12 inches is in fact 25/32 inch by 11½ inches. This must be taken into account in computing the amount of lumber needed for a given job. Thus, one hundred 1-inch by 12-inch dressed boards

needed for a given job. Thus, one hundred  $1\text{-inch by } 12\text{-inch}$  dressed boards  
$$100 \times 1 \times 12 \times \frac{12}{16} = 1,600 \text{ board feet, but have an}$$

16 feet long contain  
$$100 \times 11\frac{1}{2} \times \frac{16}{12} = 1,533 \text{ square feet; so that if } 1,600$$

actual area of only 12 square feet of 1-inch by 12-inch material are desired, 1,670 board feet, plus allowance for wastage, must be ordered.

(2) Table 16--5 gives the number of board feet in one piece of lumber for the common sizes given. For other sizes use multiples of values given (i.e. for a 2 x 8 use the value for the 2 x 4 doubled).

(3) Table 16--6 gives nominal size, dressed size, section area, and weight per foot of the most common sizes of southern pine timbers.

b. *International Log Rule.* The board measure of volume of a log can be estimated by measuring the diameter at the small end (do not include the bark) and using table 16--7.

## 16-5. NAILS AND FASTENERS

a. *Nails and Spikes.* The safe lateral load for one nail or spike driven into the side grain of seasoned lumber (so that at least two-thirds of the length of the nail is in the wood member holding the point) is as follows (reduce load 60 percent for nails in end grain and 25 percent for unseasoned wood):



Table 16--5. Board Feet

Size of piece (inches)	Length of piece (feet)							
	10	12	14	16	18	20	22	24
2 by 4	6 $\frac{1}{3}$	8	9 $\frac{1}{3}$	10 $\frac{2}{3}$	12	13 $\frac{1}{2}$	14 $\frac{2}{3}$	16
2 by 6	10	12	14	16	18	20	22	24
2 by 10	16 $\frac{2}{3}$	20	23 $\frac{1}{3}$	26 $\frac{2}{3}$	30	33 $\frac{1}{3}$	36 $\frac{2}{3}$	40
2 by 14	23 $\frac{1}{3}$	28	32 $\frac{2}{3}$	37 $\frac{1}{3}$	42	46 $\frac{2}{3}$	51 $\frac{1}{3}$	56
3 by 6	15	18	21	24	27	30	33	36
3 by 8	20	24	28	32	36	40	44	48
3 by 10	25	30	35	40	45	50	55	60
3 by 14	35	42	49	56	63	70	77	84
4 by 4	13 $\frac{1}{3}$	16	18 $\frac{1}{3}$	21 $\frac{1}{3}$	24	26 $\frac{2}{3}$	29 $\frac{1}{3}$	32
4 by 6	20	24	28	32	36	40	44	48
4 by 10	33 $\frac{1}{3}$	40	46 $\frac{2}{3}$	53 $\frac{1}{3}$	60	66 $\frac{2}{3}$	73 $\frac{1}{3}$	80
4 by 14	46 $\frac{2}{3}$	56	65 $\frac{1}{3}$	74 $\frac{2}{3}$	84	93 $\frac{1}{3}$	102 $\frac{2}{3}$	112
6 by 6	30	36	42	48	54	60	66	72
6 by 8	40	48	56	64	72	80	88	96
6 by 10	50	60	70	80	90	100	110	120
6 by 14	70	84	98	112	126	140	154	168
6 by 18	90	108	126	144	162	180	198	216
8 by 8	53 $\frac{1}{3}$	64	74 $\frac{2}{3}$	85 $\frac{1}{3}$	96	106 $\frac{2}{3}$	117 $\frac{1}{3}$	128
8 by 10	66 $\frac{2}{3}$	80	93 $\frac{1}{3}$	106 $\frac{2}{3}$	120	133 $\frac{1}{3}$	146 $\frac{2}{3}$	160
8 by 12	80	96	112	128	144	160	176	192
8 by 14	13 $\frac{1}{3}$	112	130 $\frac{2}{3}$	149 $\frac{1}{3}$	168	186 $\frac{2}{3}$	205 $\frac{1}{3}$	224

NOTE For other dimensions use multiples of above values. (i.e., for 12 x 10 use the value of a (6 x 10) x 2).

NOMINAL SIZE	ACTUAL SIZE DRESSED S S	AREA OF SECTION BD. A. SQ. INS.	WEIGHT PER FOOT (POUNDS)
2 x 4	1 5/8 x 3 5/8	5.89	1.63
4 x 4	3 5/8 x 3 5/8	13.14	3.64
2 x 6	1 5/8 x 5 5/8	9.14	2.53
6 x 6	5 5/8 x 5 5/8	31.64	8.76
2 x 8	1 5/8 x 7 1/2	12.19	3.38
4 x 8	3 5/8 x 7 1/2	27.19	7.55
6 x 8	5 5/8 x 7 1/2	42.19	11.72
8 x 8	7 1/2 x 7 1/2	56.25	15.58
2 x 10	1 5/8 x 9 1/2	15.44	4.28
6 x 10	5 5/8 x 9 1/2	53.44	14.84
10 x 10	9 1/2 x 9 1/2	90.25	25.00
2 x 12	1 5/8 x 11 1/2	18.69	5.18
3 x 12	2 5/8 x 11 1/2	30.19	8.39
6 x 12	5 5/8 x 11 1/2	64.69	17.96
8 x 12	7 1/2 x 11 1/2	86.25	23.89
10 x 12	9 1/2 x 11 1/2	109.25	30.26
2 x 14	1 5/8 x 13 1/2	21.94	6.09
3 x 14	2 5/8 x 13 1/2	35.44	9.84
6 x 14	5 5/8 x 13 1/2	75.94	21.09
10 x 14	9 1/2 x 13 1/2	128.25	35.53
14 x 14	13 1/2 x 13 1/2	182.25	50.48
2 x 16	1 5/8 x 15 1/2	25.19	7.00
3 x 16	2 5/8 x 15 1/2	40.69	11.30
8 x 16	7 1/2 x 15 1/2	116.25	32.20
12 x 16	11 1/2 x 15 1/2	178.25	49.37
14 x 16	13 1/2 x 15 1/2	209.25	57.96
16 x 16	15 1/2 x 15 1/2	240.25	66.55
4 x 18	3 5/8 x 17 1/2	63.44	17.62
8 x 18	7 1/2 x 17 1/2	131.25	36.36
12 x 18	11 1/2 x 17 1/2	201.25	55.75

\*IN SOME SPECIES 5 1/2" IS THE DRESSED  
SIZE FOR NOMINAL 6" x 6" AND LARGER.

Table 16-7. Log Scale (Board Measure of Volume)

Diameter (Inches)	Length of log in feet (board measure)						
	8	10	12	14	16	18	20
6	10	10	15	15	20	25	25
8	15	20	25	35	40	45	50
10	30	35	45	55	65	75	85
12	45	55	70	85	95	110	110
14	65	80	100	115	135	155	175
16	85	110	130	155	180	205	235
18	110	140	170	200	230	265	300
20	135	175	210	250	290	330	370
24	205	255	310	370	425	485	545
28	280	355	430	510	585	665	745
32	375	470	570	670	770	875	980
36	475	600	725	855	980	1115	1245
40	595	750	900	1060	1220	1380	1540
44	725	910	1095	1290	1480	1675	1870
48	865	1090	1310	1540	1770	2000	2235

900 x D<sup>3/2</sup> for white pine and eastern hemlock  
 1200 x D<sup>3/2</sup> for Douglas fir and southern yellow pine  
 1700 x D<sup>3/2</sup> for oak, ash, and hard maple

Where D = diameter of nails, in inches. See table 16-8.

b. *Wood Screws.* The safe lateral load, in pounds, for one wood screw, driven into the side grain of seasoned lumber to a penetration of at least seven times the diameter into the member receiving the point, is as follows (reduce load 25 percent for end grain and 25 percent for unseasoned wood):

2. White pine and eastern hemlock

Table 16-8. Nail and Spike Sizes

SIZE	LENGTH, IN	COMMON				FINISHING		FLOORING	
		DIAMETER (D)							
		GAGE	NO./LB	INCHES	D3/2	GAGE	NO./LB	GAGE	NO./LB
3D	1 1/4	14	568	.0800	.0226	15 1/2	807		
4D	1 1/2	12 1/2	316	.0985	.0309	15	584		
6D	2	11 1/2	181	.1130	.0380	13	309	11	157
8D	2 1/2	10 1/4	106	.1314	.0476	12 1/2	189	10	99
10D	3	9	69	.1483	.0570	11 1/2	121	9	69
12D	3 1/4	9	63	.1552	.0611	11 1/2	113	8	54
16D	3 1/2	8	49	.1620	.0652	11	90	7	43
20D	4	6	31	.1920	.0841	10	61	6	31
30D	4 1/2	5	24	.2070	.0942				
40D	5	4	18	.2253	.1066				
60D	6	2	11	.2625	.1347				
SPIKES						NOTE: TO AVOID SPLITTING, NAIL DIAMETERS SHOULD NOT EXCEED ONE-SEVENTH OF THE THICKNESS OF LUMBER TO BE NAILED.			
7"	7"	5/16"		5/16"	0.1750				
8"	8"	3/8"		3/8"	.2295				
9"	9"	3/8"		3/8"	.2295				
10"	10"	3/8"		3/8"	.2295				
12"	12"	3/8"		3/8"	.2295				

FORMULA TO FIND APPROXIMATE NUMBER OF NAILS REQUIRED.

NO. LBS. (12D TO 60D, FRAMING) =  $D/6 \times BF/100$

NO. LBS (2D TO 12D, SHEATHING) =  $D/4 \times BF/100$

WHERE D = SIZE OF DESIRED NAIL IN PENNIES

BF = TOTAL BOARD FEET TO BE NAILED

Table 16-9. Wood Screw Diameters

Size	Diameter-D Inches	D <sup>2</sup> Inches <sup>2</sup>
½ inch—No. 4	0.1105	0.0122
¾ inch—No. 8	.1631	.0266
1 inch—No. 10	.1894	.0359
1½ inch—No. 12	.2158	.0466
2 inch—No. 14	.2421	.0586
2½ inch—No. 16	.2684	.0720
3 inch—No. 18	.2947	.0868

1900 x D<sup>2</sup> for southern yellow pine and soft maple

2200 x D<sup>2</sup> for oak, ash, and hard maple

Where D = diameter of shank, in inches.

c. *Lag Screws.* The safe lateral load, in pounds, for one lag screw, driven into the side grain of seasoned lumber to a penetration of nine times the diameter into the member receiving the point, and holding a cleat having a thickness of 3.5 times the screw diameter, is as follows (reduce load 35 percent for end grain and 25 percent for unseasoned wood):

1500 x D<sup>2</sup> for white pine and eastern hemlock

1700 x D<sup>2</sup> for Douglas fir and southern cypress

d. *Driftpins.*

(1) *Description.* "Driftpins" (or "driftbolts") are long, heavy, threadless bolts or bars used to hold heavy pieces of timber together. Driftpins may or may not have heads and vary in diameter from ½ to 1 inch, and in length from 18 to 26 inches.

(2) *Use.* To use the driftpins, a hole slightly smaller than the diameter of the pin is made in the timber. The pin is wiped with oil, driven

*a. Factors of Recognition.* When camouflaging activities, personnel, equipment, or installations, the camouflage should try to alter or eliminate the six factors of recognition as much as possible. The six factors are as follows:

- (1) Shape
- (2) Shadow
- (3) Color
- (4) Texture
- (5) Position
- (6) Movement

*b. Principles.*

- (1) *Siting.* Careful selection of the position for an emplacement of equipment is the most important principle of camouflage. Emplacements and their artificial camouflage materials must be made to blend with their background.
- (2) *Discipline.* Avoid unnecessary movement of personnel and vehicles and any other activity that would change the original appearance of the area and indicate your presence to enemy observers.
- (3) *Construction.* Employ natural and artificial construction and camouflage materials to conceal the position.

*c. Materials.*

- (1) *Natural.* Natural materials generally provide the best concealment and are always available. Natural materials include live vegetation, cut vegetation, debris, soil, and so forth.
- (2) *Artificial Material.* Artificial materials include paints, supporting frames, garnishing materials, structural materials, screening materials, adhesives, and texturing materials. See table 6--10 for expedient paints that can be made from materials readily available. FM 5--35 has more detail on camouflage materials and man-hour requirements involved.
- (3) *Lightweight Camouflage Screen.* The lightweight camouflage screens are issued in two type, radar scattering and radar transparent. The basic issue is by module (screen and supports). Multiple screens can be joined together to provide larger screens (see figs. 16--1 and 16--2). The camouflage screens are issued in these color type.

- (a) Woodland blend, a reversible spring/summer and fall/winter screen.
- (b) Desert blend, a reversible desert grey and desert tan.
- (c) Snow blend.

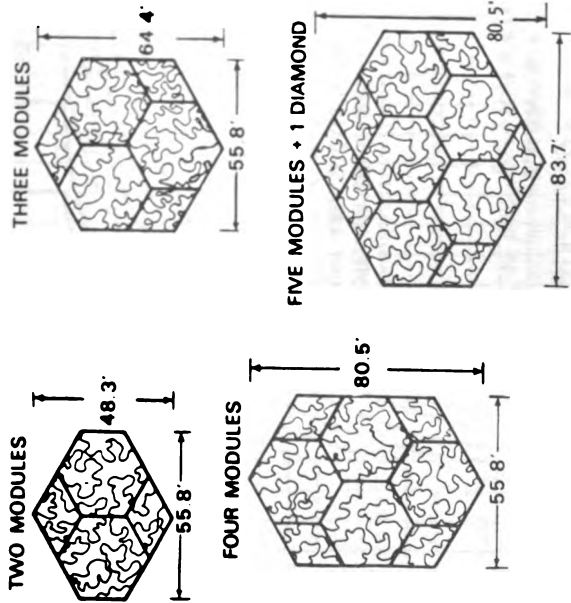
*Table 16-10. Expedient Paints*

Paint	Materials	Mixing	Color	Finish
No. 1	Local earth, GI soap, water, soot paraffin	Mix soot with paraffin; add to solution of 8 gal water and ½ lbs soap. Stir in earth	Dark gray	Flat, lusterless
No. 2	Oil, ground clay, water, gasoline, earth	Mix 2 gal water with 1 gal oil and ½ to ¾ gal clay; add earth. Thin with gasoline or water	Depends on earth colors available	Glossy on metal; otherwise dull
No. 3	Oil, clay, GI soap, water, earth	Mix 1½ bars GI soap with 3 gal water; add 1 gal oil; stir in 1 gal clay. Add earth for color	Depends on earth colors	Glossy on metal; dull on other

*NOTE:* Canned milk or powdered eggs can be used to increase binding properties



Note: Diamond and hexagon screens may be used separated or joined.



Note: All hexagon and diamond shaped nets are fastened together with quick-release connectors.

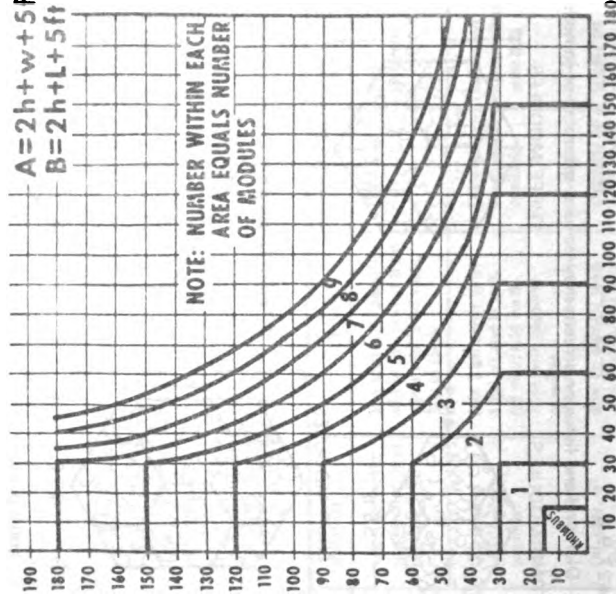
Figure 16--1. Lightweight camouflage screens.



# HASTY MODULE DETERMINATION CHART

$$A = 2h + w + 5\text{ft}$$

$$B = 2h + L + 5\text{ft}$$



**B (FEET)**

**NOTE:** This chart is normally reliable for vehicles of regular configuration. Vehicles of irregular

clothing to the terrain, and select a route during which everyone there remains covered by the concealment available.

(1) *Helmets.* Break up the shape of helmets by using leaves or twigs secured with a rubber band, making a cover of burlap, distorting with burlap garlands, or painting appropriate colors.

(2) *Skin.* Tone down all visible skin areas with face paint, burnt cork, lampblack, or charcoal (use a non-shine substance).

(3) *Clothing.* Clothing may be toned down to blend with the background by the use of camouflage paints, or attaching vegetation to blend in with existing area.

(4) *Equipment.* Remove shine from metal objects with mud or face paint. Any equipment which may make a noise should be muffled by padding.

*e. Camouflage of Equipment and Emplacements.*

(1) All military vehicles and equipment have regular geometric configurations or characteristic shapes and interior shadow. These so-called signatures contrast with natural surroundings and make the object conspicuous. To make the item less conspicuous, the identifying characteristics of shape, shadow, and highlights must be disrupted in a manner that makes military vehicles and equipment more difficult to perceive. Natural camouflage material supplemented with artificial materials such as pattern painting with lusterless camouflage paint, contributes significantly toward disrupting the signature characteristics of military vehicles and equipment. Avoid regular geometric layouts of the position of vehicles, weapons, and supplies.

(2) Conceal the tracks made by vehicles so that terrain remains the same.

(3) Eliminate shine on vehicles.

(4) Use shadows and insure that the silhouette of emplacements and equipment is broken so that the general outline is not detectable.

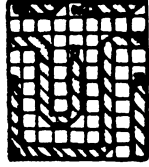
(5) In urban areas, use shadows cast by buildings.

*f. Garnishing of Camouflage Nets.*

(1) *Garnishing density.* Drape nets should be garnished 100 percent in the center portion of the net, thinning out to 65 percent toward the outer edges. This will result in a coverage of about 85 percent of the entire net area. Flattop nets should be garnished 100 percent in the center portion of

the net, thinning out to 25 percent toward the outer edges. This will result in a coverage of about 65 percent of the entire net area. Begin the thin-out at about one-half the radius of the net. This must not be on an abrupt change in percentages, but rather a gradual thinning-out so as to achieve a smooth transition to the desired density at the outer portion of the net.

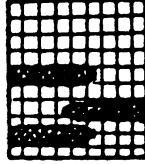
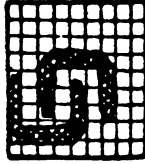
(2) *Garnishing Patterns.* To provide for blending into a variety of seasonal and geographic terrain characteristics, pregarnished twine nets are issued in two blends--the all seasonal and the desert. The color blend of a net is achieved by proportionately varying the garlands of the various colors required for a particular blend, and placing the garlands in the net as an overall mixture of colors. Long, straight runs, large areas, blocks of one color, or regularity of pattern in a net should be avoided. Generally, the garlands are inserted into the net in such a manner that each garland will describe one of the following letters: L, U, S, C, or 1 (fig. 16--3). This should result in an amalgamation of the letter pattern forming the desired degree of density and color blend.



L PATTERN

U PATTERN

S PATTERN



C PATTERN

I PATTERN

g. *Calculation of Net Size.*

(1) *Drape net.*

$$\text{Length} = 2H + L + 5'$$

$$\text{Width} = 2H + W + 5'$$

(2) *Flat top net.*

$$\text{Length} = 4(H + 2) + L$$

$$\text{Width} = 4(H + 2) + W$$

Where:

L = length of object being camouflaged

W = width of object being camouflaged

H = height of object being camouflaged

## 16-7. VEHICLE RECOVERY EXPEDIENTS

a. *General.* For a complete coverage of all aspects of vehicle recovery see FM 20-22.

b. *Field Expedient Vehicle Recovery.* See figures 16-4 thru 16-7.

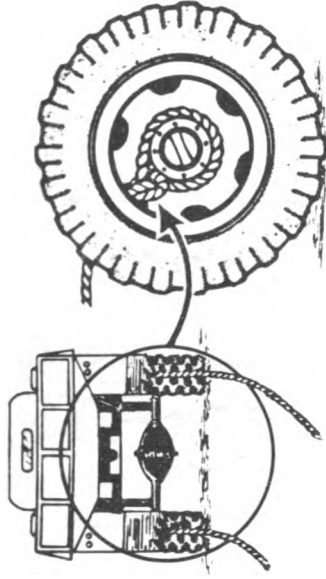
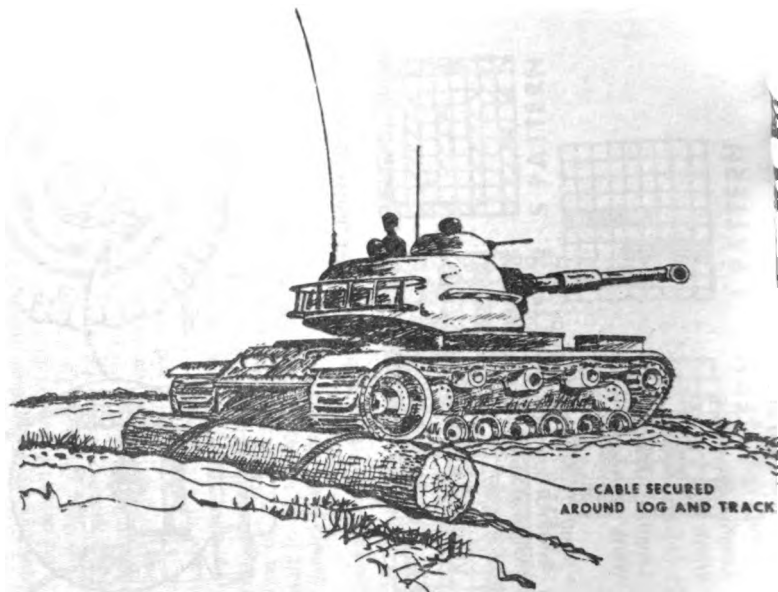


Figure 16-4. Use of dual wheels for a winch.



**Figure 16-5. Log used to provide track traction.**



Figure 16-6. Simple lever.

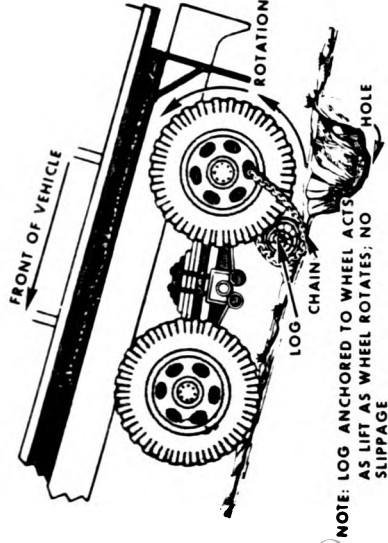


Figure 16-7. Log used to provide wheel traction.

## 16-8. FLAME FIELD EXPEDIENTS

a. *General.* Flame field expedients are flame devices improvised in the field. They are usually used in the defense but could be employed in offensive operations. They are used for their incendiary, illuminating, and signalling effects.

b. *Materials and Equipment Required.* See figure 16-8.

- (1) Fuel ingredients (gasoline and M4 thickener)
- (2) Wooden mixing/measuring paddle
- (3) Container (5 to 55 gals) (nongalvanized)
- (4) Burster to scatter fuel (M4 burster, det cord, or other explosive)
- (5) Igniter (when M4 burster is not used)
- (6) Bucket and funnel (to transfer mixed fuel to container)

Caution: Insure no open flames in or near mixing/storage site. Do not put hands in gas. Keep out of eyes and mouth. Never mix inside a tent or building. Have carbon dioxide fire extinguishers available when mixing.

c. *Mixing Procedure.* (gasoline: 32° to 85° F)

- (1) Quantity of M4 thickener

Rule of Thumb: ounces of M4 thickener = gals of gasoline x 3  
(constant)

Example:

M4 = 40 gals of gasoline x 3

M4 = 120 ounces (7½ lbs)

(use 3 — 2½ lbs cans of M4 thickener)

- (2) Add unclotted M4 thickener to gasoline while stirring.

- (3) Mix till applesauce texture is achieved (5-10 minutes).

- (4) Allow the fuel to age from 6 to 8 hours. (Can be employed while

aging)

d. *Types of Flame Field Expedients.*

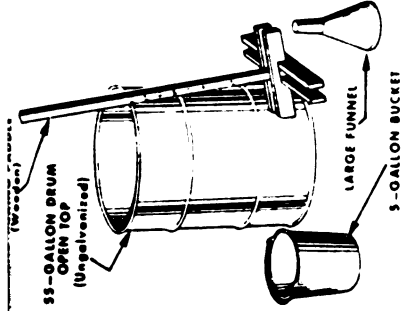
- (1) *Exploding Flame Device:* see figure 16-9.

(a) area of coverage:

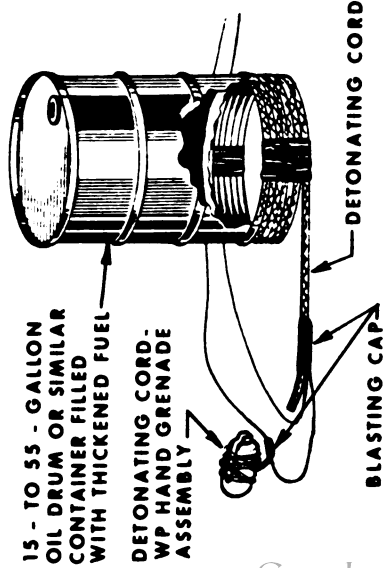
5 gal = 20-30 meters

55 gal = 85 meters

(b) Detonator:



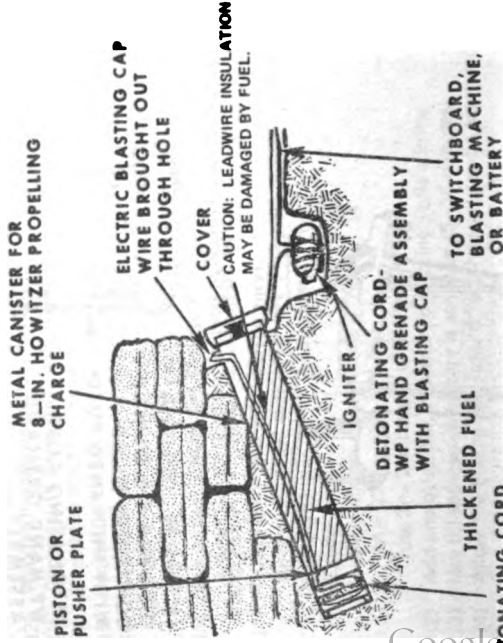
*Figure 16-8. Equipment used in handmixing flame fuel.*



*Figure 16-9. Exploding 55 gallon flame device.*



(2) *Flame Fougasse*: a variation of an exploding flame device. The direction of burst is controlled. See figure 16-10.



**DETONATING CORD.  
3-5 CIRCLES, FLATTENED  
SIDE BY SIDE  
ENCASED IN PLASTIC BAG  
(TNT or Claymore can be used)**

(3) *Flame Illuminator.* The Hush-type flare (figures 16-11) will illuminate a radius of 50 meters for 4-5 hours.

(u) *Materials for construction.*

- 1 Sealed metal container (powder canister)  $\frac{3}{4}$  full of thickened fuel
- 2 Half of a 55 gal drum  $\frac{3}{4}$  full of thickened fuel
- 3 Reflector (24" culvert half)
- 4 Igniter (tripflare or WP grenade)

(b) *Method of operation.*

- 1 Place the metal container, cap down, into 55 gal half drum of thickened fuel (bottom with the 1/8 hole up).
- 2 When the half drum is ignited, the heat from the burning fuel produces vapor inside the metal container which is expelled as a flaming jet through the hole.
- 3 The reflector (culvert) should extend about 60 centimeters above the top rim of the drum.

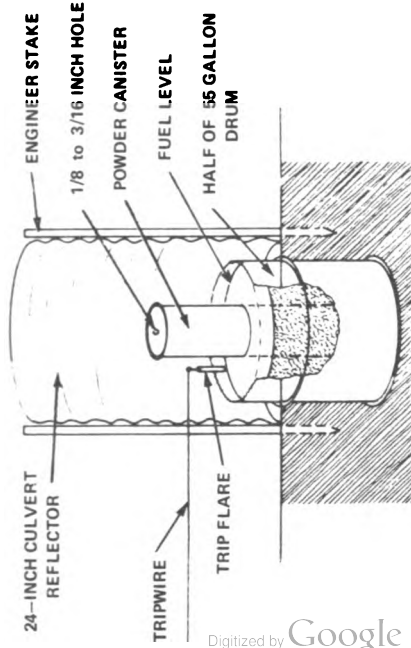


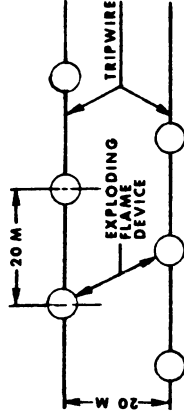
Figure 16-11. Hush-type flare.

e. *Methods of Firing.*

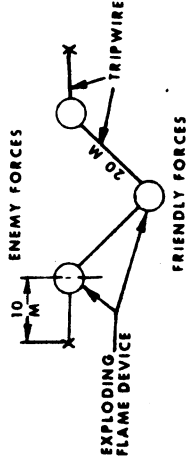
- (1) May be wired to fire electrically on an individual basis, in groups, or simultaneous ignition.
- (2) Can be rigged with trip wires for immediate or delayed firing.

NOTE: Electric and nonelectric blasting caps can be used with various burster/igniters.

f. *Emplacement of Flame Field Expedients.* Two basic patterns for emplacement are shown in figure 16-12.



PARALLEL EMPLACEMENT



TRIANGLE EMPLACEMENT

NOTE:

BECAUSE THERE ARE BUT 51 M TRIPWIRE ISSUED WITH FIVE OF THE FUZES, WHERE 93 M ARE REQUIRED FOR PROPER EMPLACEMENT OF FIVE UNITS, SUBSTITUTE MATERIAL FOR TRIPWIRES MUST BE USED. IT IS SUGGESTED THAT TELEPHONE WIRE BE USED BECAUSE OF ITS DARK COLOR, AVAILABILITY, AND CASUAL APPEARANCE. TELEPHONE WIRE MAY ALSO BE USED AS A LANYARD ATTACHED TO THE TRIPWIRE AND RUN BACK TO A FIRING BUNKER.

- a. Table 16-11 gives the formulas for solving right and oblique triangles.  
 b. Table 16-12 gives the natural trigonometric functions.

Table 16-11. Trigonometric Solution of Triangles

		RIGHT TRIANGLE				OBLIQUE TRIANGLE			
		TO FIND				TO FIND			
GIVEN		A	B	C		A	B	C	
a, b		$\tan A = \frac{a}{b}$	$\tan B = \frac{b}{a}$	$90^\circ$		$\frac{A}{\cos \frac{A}{2}} = \sqrt{\frac{s(s-a)}{bc}}$	$\frac{B}{\cos \frac{B}{2}} = \sqrt{\frac{s(s-b)}{ac}}$	$\frac{C}{\cos \frac{C}{2}} = \sqrt{\frac{s(s-c)}{ab}}$	AREA
a, c		$\sin A = \frac{a}{c}$	$\cos B = \frac{a}{c}$	$90^\circ$				$180^\circ - (A + B)$	$\frac{a^2 \sin B \sin C}{2 \sin A}$
A, a			$90^\circ - A$	$90^\circ$			$\sin B = \frac{b \sin A}{a}$		$\frac{a^2 \sin B \sin C}{2 \sin A}$
A, b			$90^\circ - A$	$90^\circ$			$\tan A = \frac{a \sin C}{b - a \cos C}$		$\frac{a^2 \sin C}{2 \sin A}$
A, c			$90^\circ - A$	$90^\circ$					$\frac{a^2 \sin C}{2 \sin A}$
a, b, c									$\frac{a^2 \sin C}{2 \sin A}$

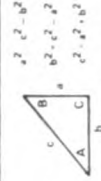
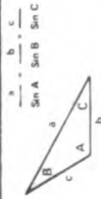
$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$a^2 = b^2 + c^2 - 2bc \cos A$$

$$b^2 = a^2 + c^2 - 2ac \cos B$$

$$c^2 = a^2 + b^2 - 2ab \cos C$$

$$S = \frac{a+b+c}{2}$$



$$\sin A = \frac{a}{c}$$

$$\cos A = \frac{b}{c}$$

$$\tan A = \frac{a}{b}$$

Table 16-12. *Natural Trigonometric Functions*

Angle	Sin	Cosine	Tan	Cotang	Sec	Csc
0°	.000		.000		1.000	90°
1°	.017	97.30	.017	57.29	1.000	89°
2°	.035	28.65	.035	28.64	1.001	88°
3°	.052	19.11	.052	19.08	1.001	87°
4°	.070	14.34	.070	14.30	1.002	86°
5°	.087	11.47	.087	11.43	1.004	85°
6°	.105	9.587	.105	9.514	1.005	84°
7°	.122	8.208	.123	8.144	1.008	83°
8°	.139	7.186	.141	7.118	1.010	82°
9°	.156	6.392	.158	6.314	1.012	81°
10°	.174	5.759	.176	5.671	1.015	80°
11°	.191	5.241	.194	5.148	1.019	79°
12°	.208	4.810	.213	4.705	1.022	78°
13°	.225	4.445	.231	4.331	1.026	77°
14°	.242	4.134	.249	4.011	1.031	76°
15°	.259	3.864	.268	3.732	1.036	75°
16°	.276	3.628	.287	3.487	1.040	74°
17°	.292	3.420	.306	3.271	1.046	73°
18°	.309	3.238	.325	3.078	1.051	72°
19°	.326	3.072	.344	2.904	1.058	71°
20°	.342	2.924	.364	2.747	1.064	70°
21°	.358	2.790	.384	2.605	1.071	69°
22°	.375	2.669	.404	2.475	1.079	68°
23°	.391	2.559	.424	2.356	1.086	67°
24°	.407	2.459	.446	2.246	1.095	66°
25°	.423	2.368	.468	2.145	1.103	65°
26°	.438	2.281	.488	2.050	1.113	64°
27°	.454	2.203	.510	1.963	1.122	63°
28°	.469	2.130	.532	1.881	1.133	62°
29°	.485	2.063	.554	1.804	1.143	61°
30°	.500	2.000	.577	1.732	1.155	60°
31°	.515	1.942	.601	1.664	1.167	59°
32°	.530	1.887	.625	1.600	1.179	58°
33°	.545	1.839	.649	1.540	1.192	57°
34°	.559	1.798	.675	1.483	1.208	56°
35°	.574	1.763	.700	1.428	1.221	55°
36°	.588	1.731	.727	1.376	1.236	54°
37°	.602	1.692	.754	1.327	1.252	53°
38°	.616	1.654	.781	1.280	1.269	52°
39°	.629	1.599	.810	1.235	1.287	51°
40°	.643	1.556	.839	1.192	1.305	50°
41°	.656	1.524	.869	1.150	1.325	49°
42°	.669	1.494	.900	1.111	1.346	48°
43°	.682	1.466	.933	1.072	1.367	47°
44°				1.034	1.389	46°

a. *Legend.*

A = area  
h = height  
b = length of base  
c = hypotenuse  
C = circumference  
V = volume  
r = radius  
D = diameter  
 $\pi = 3.1416$   
L = length of arc  
K = length of cord

b. *Formulas*

(1) Any triangle:

$$A = 1/2 bh$$

$$\text{or: } \sin \gamma = \frac{c \sin \phi}{a}$$

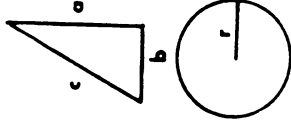


(2) Right triangle:

$$a = \sqrt{c^2 - b^2}$$

$$b = \sqrt{c^2 - a^2}$$

$$c = \sqrt{a^2 + b^2}$$



(3) Circle:

$$A = \pi r^2$$

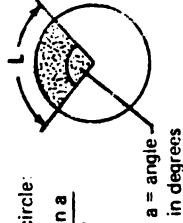
$$A = 0.7854 D^2$$

$$C = \pi D$$

- (4) Segment of circle:

$$A = \frac{\pi r^2 a}{360} - \frac{r^2 \sin a}{2}$$

$$L = \frac{2\pi ra}{360}$$



- (5) Sector of circle:

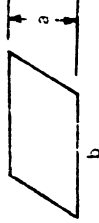
$$A = \frac{rL}{2} = \frac{\pi r^2 a}{360}$$



(6) *Regular polygons.* The area of any regular polygon (all sides equal, all angles equal) is equal to the product of the square of the lengths of one side and the factors shown in table 16-13. Example problem: Area of a regular octagon having 6-inch sides is  $6 \times 6 \times 4.828$ , or 173.81 square inches. See factors in table.

- (7) Rectangle and parallelogram

$$A = ab$$



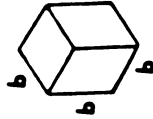
- (8) Trapezoid:
- 
- $$A = \frac{1}{2}a(b_1 + b_2)$$



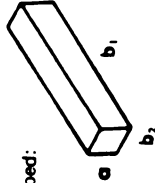
times sum of two end widths plus twice the sum of the interval between offsets

(b) *Simpson's rule.* (Assumes lateral boundaries are parabolic curves.)  $A =$  one-third the interval between offsets times sum of two end widths plus twice the sum of the interval between offsets times sum of two end widths plus twice the sum of the odd widths, except first and last (3rd, 5th, 7th, etc.) plus 4 times the sum of the even widths (2nd, 4th, 6th, etc.)

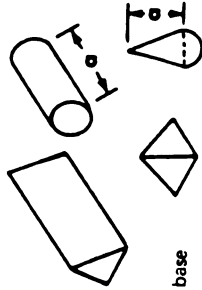
*Note:* The above rule required an odd number of widths. If there is an even number, compute separately the area of a trapezoid at one end.



- (10) Cube:  
 $V = b^3$



- (11) Rectangular parallelepiped:  
 $V = ab, b_2$



- (12) Prism or cylinder:  
 $V = a \times \text{area of base}$

- (13) Pyramid or cone:  
 $V = (1/3)a \times \text{area of base}$



(14) Sphere:

$$V = \frac{(4/3)\pi r^3}{6} = \frac{\pi D^3}{6}$$

$$A = 4\pi r^2$$



(15) *Prismoidal section.*  $V$  = one-sixth the length times (sum of the end areas plus 4 times the midsection area)

Table 16-13. *Polygon Factors*

No. of sides	Factor	No. of sides	Factor
3	0.433	8	4.828
4	1.000	9	6.182
5	1.720	10	7.694
6	2.598	11	9.366
7	3.634	12	11.196

## 16-11. TROOP MOVEMENT FACTORS

- Rates of March.* See table 16-14.
- March Formulas.* See table 16-15.

## 16-12. INFANTRY WEAPONS

Table 16 34 Rates of Marches

Unit	Average Rates of March (KMPH) <sup>2</sup>					Days March Kilo meters
	On Roads		Cross country			
			Day	Night		
	Day	Night	Day	Night		
Foot troops	4	3.2	2.4	1.6	20-32	
Trucks, general	40	40 (lights) 16 (black out)	12	8	280	
Tracked vehicles	24	24 (lights) 16 (black out)	16	8	240	
Truck-drawn artillery	40	40 (lights) 16 (black out)	12	8	280	
Tractor-drawn artillery	32	32 (lights) 16 (black out)	16	8	240	

<sup>1</sup> This table is for general planning and comparison purposes. All rates given are variable in accordance with the movement conditions as determined by reconnaissance.

<sup>2</sup> These rates include normal periodic rest halts.

Table 16-15. March Formulas and Factors

METRIC CONVERSION FACTORS  
SEE TABLE 16-19

FOR TIME DISTANCE (TD): TD (HOURS) =  $\frac{D \text{ (KILOMETERS)}}{R \text{ (KILOMETERS PER HOUR)}}$

FOR TIME LENGTH (TL) (FOOT COLUMN): TL (MIN) = RS (ROAD SPACE) X FACTOR

<u>RATE (KMPH)</u>	<u>FACTOR</u>
4.0	.0150
3.2	.0187
2.4	.0250
1.6	.0375

FOR ROAD SPACE (RS) OF FOOT TROOPS: RS (METERS) = (NO. OF MEN X FACTOR) + DISTANCES BETWEEN UNITS

<u>FORMATION</u>	<u>2M/MAN</u>	<u>5M/MAN</u>
SINGLE FILE	2.4	5.4
COLUMN OF TWO'S	1.2	2.7

FOR TIME LENGTH (TL) VEHICLES (OPEN COLUMN): TL (MINUTES) = (NO. OF VEHICLES X FACTOR) + T1'S (TIME INTERVALS BETWEEN UNITS)

<u>RATE (KMPH)</u>	<u>M/VEH</u>	<u>FACTOR</u>
16	100	.3750
24	100	.2500
32	100	.1875
40	100	.1500
48	100	.1250

FOR TIME LENGTH (TL) OF MOTORS (CLOSE COLUMN): TL (MINUTES) = (NO. OF VEHICLES X 12) + T1'S

FOR COMPLETION TIME (CT): CT = IP TIME + TL + TD + SCHEDULED HALTS

EXAMPLE:	<u>HR</u>	<u>MIN</u>
	07	45
	01	12
	05	55
	01	00
	CT = 14	112
		OR 1552 HOURS

FOR ROAD SPACE (RS) OF VEHICLES:

Digitized by

Table 16-16. Characteristics of Infantry Weapons and Ammunition

WEAPON	UNLOADED WEIGHT LBS	TYPE OF FEED	METHOD OF OPERATION	CYCLIC OR MAX RATE OF FIRE	MAX MAX EFFECTIVE RANGE METERS	AMMUNITION PACK	AMMUNITION WEIGHT LBS PACKED	BASIC LOAD OF AMMO PER MAN WPN	REMARKS
PISTOL M1911 A1 CAL 45	2 1/2 LBS	7 RD MAG	RECOIL SEMI AUTO	35-42 M	1500/50	50 RDS BOX 20 BOX CAN 2 CAN CASE	113	21	
RIFLE M14 M14 A1 7.62 MM	9.84 12.12	20 RD MAG	GAS SEMI AUTO & AUTO	700-750 C.	3725/460 3725/700 SA /460 A	5 RD CLIPS 12 CLIPS BAND 7 BAND CAN 2 CANS/CASE	69	160 160/760	SELECTOR MUST BE INSTALLED BYOD AVAILABLE WHEN USED AS AUTOMATIC RIFLE
RIFLE M16 A1 5.56 MM	6 1/2	30 RD MAG	GAS SEMI AUTO & AUTO	700-800	2653-460	10 RD CLIPS 14 CLIPS BAND 6 BAND CAN 2 CANS BOX	85	210	MAY BE ISSUED WITH A BYOD WHEN USED AS AR
MACHINE GUN M60 7.62 MM	23	BELT METALIC SPLIT LINK	GAS AUTO	550(C)	3725/1100	220 BELT 1 BELT CAN 4 CANS BOX	75	2,200	EFFECTIVE RANGE BASED ON GUNNERS ABILITY
MACHINE GUN HB M2 CAL	MG 84 MT. 44	BELT METALIC SPLIT LINK	RECOIL SEMI AUTO & AUTO	450-500	6800/725 AA /1830 GND	105 BELT 1 BELT/CAN 2 CANS/CASE		2,100/ WPN	USED IN ANTI-AIRCRAFT OR GROUND ROLE
SHOTGUN RGT TYPE 12 GAUGE 2.75 IN	7 1/2	5 RD TUBE	MANUAL (PUMP)	5	DEPENDS ON TYPE OF SHOT	12 CARTON 20 CARTON/CASE	45	10	
GRENADE LAUNCHER M79 M 203 40 MM	6/3	SINGLE SHOT	PERCUSSION	2-4	400/150-PT TGT /350-AREA TGTS	12 /BAND 12 BAND/BOX	9/BAND - LEER	30	MINIMUM SAFE RANGE: COMBAT, 31M TRNG: 80 M ARM DISTANCE: 14-28 M EFFECTIVE BURST RADIUS: 5M

Table 16 - 16. Characteristics of Infantry Weapons and Ammunition (Con't)

WEAPON	UNLOADED WEIGHT (LBS)	TYPE OF FEED	METHOD OF OPERATION	CYCLIC (C) OR MAX (M) RATE OF FIRE	MAX/MAX EFFECTIVE RANGE (METERS)	AMMUNITION PACK	AMMUNITION WEIGHT (LBS) (PACKED)	BASIC LOAD OF AMMO PER MAN/WPN	REMARKS
HAND GRENADE FRAG— M 67 M 68 WP M 34	1 1 1 1/2		ELECTRICAL IMPACT FUZE 4-5 SEC. DELAY		APPROX. 35 M DEPEN- DENT ON THROWING DISTANCE OF INDIVIDUAL	1 /CTN 30 CTNS/BOX	2/GRENADE	4	BURSTING  15 M 15 M 25 M (60 BUR
MINE ANTI-PERS. M18 A1 CLAYMORE	3.5		CONTROLLED ELECTRIC OR TRIPWIRE DETONATION	ONE SHOT	250/50	1/KIT (COMPLETE) 6 KITS/CTN	6.8	10/NON-DIV ENGR BN. 2/ TRACK VEH (MECH DIV ENGR BN) 15/ DIV ENGR BN	WHEN EN- WITH TR MUST BE ED AS A AND ITS RECORDED PORTED TIONAL F SECTOR 50 METE 16 M LET (BACK & AND 100 BLAST D ZONE
ROCKET, HEAT M72A1 (LAW) 66 MM	4.7*	SINGLE SHOT THROW AWAY	MANUAL	1 SHOT	1000/200	5/CTN 3 CTNS/BOX	27 1/2 120	BY TOE	BACK BL 15 M DAN ZONE 25 CAUTION FRONT GRADUA 325 M. A AS AMM 'WEIGH'
ROCKET LAUNCHER M202 & M202 A1 4 TUBE 66 MM (FLAME)	11.5	4 RD CLIP	RECOILLESS SEMI-AUTO	1 CLIP	200 PT TGTS /50' AREA TGTS 20 MINIMUM	4 RDS/CLIP 4 CLIPS/BOX	15.1 EA 122		M74 RC FLAME LATED 13 M AR RANGE. RADIUS BACK B 40 M.

Table 16-16. Characteristics of Infantry Weapons and Ammunition (Con't)

WEAPON	UNLOADED WEIGHTS LBS	TYPE OF FEED	METHOD OF OPERATION	CYCLIC OR MAX RATE OF FIRE	MAX/MAX EFFECTIVE RANGE METERS	AMMUNITION PACK	AMMUNITION WEIGHT (LBS) (PACKED)	BASIC LOAD OF AMMO PER MAN/WPN	REMARKS
TABLE MACHINE GUN M-1	25	FUEL PROPELLED BY GAS UNDER PRESSURE	MANUAL	5-8 SECONDS CONTINUOUS	40-50	4 GALS OF THICKENED FUEL	25	IGNITION CYL-8, PEPTIZER-1 GAL, THICKENER 10 LBS	
REPELLED MACHINE GUN M-1	21,000*	FUEL PROPELLED BY GAS UNDER PRESSURE	ELECTRICAL	32 SECONDS FOR CONTINUOUS DISCHARGE	150-170	200 GALS OF THICKENED FUEL	1260		*INCLUDES WEIGHT OF M113 PERSONNEL CARRIER
BARREL BIPOD SIGHT 4 BASE 26	BARREL 28 BIPOD 40 SIGHT 4 BASE 26	MUZZLE LOADING BY HAND	DROP FIRE	12 M FOR 2 MIN	4512/4512	1 PER CARTON 4/CTNS/BOX	20 EA	120	EFFECTIVE BURSTING AREA: 25 X 20 M
BARREL BIPOD SIGHT 4 BASE 193 STANDARD ROTATOR 90	BARREL 157 BIPOD 170 BASE 193 STANDARD 60 ROTATOR 90	MUZZLE LOADING BY HAND	DROP FIRE	18 (M) FOR 1 MIN & 9 MIN FOR 5 MIN	920 MIN-IMUM 5650/5650 MAX	1 RD/ PER CTN HE ILLUM SMOKE GAS	27 26 28 24	160	40 x 20 40-90 SECONDS WP H. HD. & MT

# 16-13. REQUESTING AND ADJUSTING FIELD ARTILLERY FIRE

- a. For details refer to TC 6-135.
- b. The call for fire:

<u>Element</u>	<u>Example</u>
Identification of Observer	"DELTA SIX FOXTROT ONE EIGHT, THIS IS ALPHA FIVE CHARLIE TWO FOUR"
Warning Order    Direction    *1 (in mils)	FIRE MISSION "DIRECTION 4760" (Between 0-6400)
Location (Grid Coordinate or Shift from Known Point *2)	"GRID NV 64353797" or "FROM HILL 479, RIGHT 110, ADD 400"
Description of Target	"15 MAN PATROL IN OPEN"
Method of Engagement	
(1) Type of Adjustment	Area Fire
(2) Trajectory	High Angle
(3) Ammunition	HE
(a) Type of Projectile	VT IN Effect
(b) Type of Fuze	Converge
(4) Distribution of Fire	Adjust Fire
(5) Methods of Fire	

**NOTE:** 1. In the Field Artillery, azimuth is stated as direction and is given in degrees or in mils (1 mil = 1/6400 of a circle). Direction can be taken from a map or compass. The following are examples of reporting the

maps. Prominent terrain features, registration points, and previously fired targets are commonly used as known points.

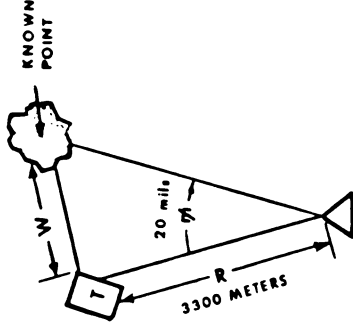
*NOTE: 3. Desired accuracy*

azimuth - nearest 10 mils

grid - 8 digit coordinate

distance - nearest 100 meters

c. *Mil Relation for Computing Deviation Corrections.* (See figure 16-14)



$$W = R \times m$$

W = Distance in meters from burst/known point to target

R = Range to target in thousands of meters

m = Angular deviation in mils

$$W = 3.3 \times 20$$

W = 66 meters - round up to 70

Figure 16-14. Mil relation for computing deviation corrections.



- d. After initial call for fire to the fire direction center (FDC), subsequent corrections are requested as shown in figure 16-15.

ROUND NO. 1: Left 70, drop 400  
 ROUND NO. 2: Add 200  
 ROUND NO. 3: Drop 100  
 ROUND NO. 4: Add 50, Fire for effect

**RULES:**

- (1) Keep rounds on observer-target line.
- (2) Bracket target during adjustment.
- (3) Confirm for effect during adjustment when:
  - (a) Split a 100 meter bracket
  - (b) Obtain a target hit
  - (c) Obtain a correct range spotting

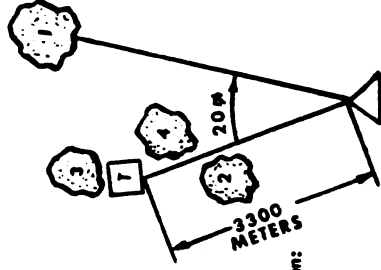
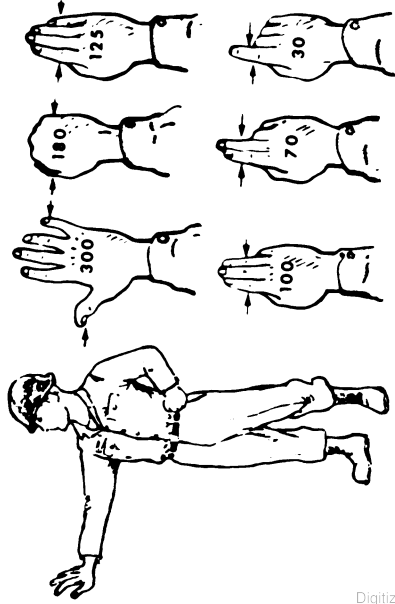


Figure 16-15. Observer procedures for adjusting field artillery fires.

Angle between target and turret is read in mils, and then distance is determined by multiplying mils by range and then dividing by 1000.

Example:  $\frac{20 \text{ mils} \times 3300 \text{ meters}}{1000} = 66 \text{ meters}$

See figure 16-16 for hasty method for estimating angle in mils.



**NOTE: ARM MUST BE FULLY EXTENDED.**

*Figure 16-16. Hasty method for estimating angle in mils.*

*f. Field Artillery Weapons.*

<u>Type</u>	<u>Range</u>
105 mm . . . . .	11,500 meters
155 mm . . . . .	14,600 meters
155 mm SP . . . . .	18,100 meters
175 mm . . . . .	32,700 meters
8 inch . . . . .	16,800 meters

*g. Field Artillery Ammunition.*

HE — high explosive  
 WP — white phosphorous  
 SMK — smoke, all colors  
 HEAT/HEPT — antitank  
 APERS — beehive  
 GAS — persistent and nonpersistent  
 Illumination

*h. Fuzes.*

Type	Fuze	Usage
Impact		Personnel/material
Quick		
Concrete Piercing		Pill boxes, bunkers, and dugouts.
Delay		
Time (airburst)		Personnel in open or in entrenchments
Mechanical		

A map is a graphic representation of a portion of the earth's surface drawn to scale on a plane.

*a. Types of Maps.*

(1) *Planimetric Map.* Presentation of only the horizontal positions for the detail plotted, with the omission of relief in a measurable form.

(2) *Topographic Map.* A map which portrays relief in a measurable form, as well as the horizontal positions of the details plotted.

(3) *Plastic Relief Map.* A topographic map preprinted on plastic materials in a three dimensional form so that the user can readily see variation in elevation.

(4) *Photomap.* A reproduction of an aerial photograph or a mosaic made from a series of aerial photographs upon which grid lines, marginal data, place names, spot elevations, boundaries, and scale have been added. Usually supplement other maps of an area.

(5) *Pictomap.* A photomap-type product which stresses the use of photolithographic operations rather than the conventional techniques used for preparation of standard maps. Heights of map features are accentuated pictorially, while terrain and vegetation are shown in near natural colors (usually published at 1:25,000 scale and larger).

*b. Map Scales.*

(1) *Small Scale Maps.* 1:600,000 through 1:5,000,000 for strategical studies at high command echelons.

(2) *Medium Scale Maps.* 1:75,000 to 1:600,000 used for planning operations including road movements.

(3) *Large Scale Maps.* 1:1,000 to 1:75,000 used to meet the tactical, technical, and administrative needs of field units.

*c. Map Colors.*

(1) *Black.* Man-made features, marginal data, and grid.

(2) *Brown.* Terrain features and contour lines depicting elevations.

(3) *Green.* Vegetation features.

(4) *Blue.* Water features.

(5) *Red.* Main roads and built-up areas.

d. *Map Marginal Data.* Marginal data, in the form of diagrams, pictures, scales and text, are printed on the sheet outside the margin of the map. Provides the user with everything needed to fulfill his map reading requirements. Data of critical importance to the Combat Engineer are:

(1) *Grid Reference Box* (usually located in the lower center margin). Contains information for composing grid reference and provides a step by step example, using a sample point on the map. Includes Grid Zone Designation (Critical if area of operations includes more than one Grid Zone.)

(2) *Bar Scales* (usually located in the lower center margin). Graphical distance scales for determining ground distance.

(3) *Contour Interval* (usually located in center lower margin below the Bar Scales). Identifies the vertical distance between contour lines.

(4) *Legend* (usually located in the lower left margin). Illustrates and identifies topographic symbols used on the map.

(5) *Declination Diagram* (usually located in the lower right margin). Graphically illustrates the relationships between Grid North (symbolized by the letters GN), True North (symbolized by a star), and Magnetic North (symbolized by a half arrowhead). Typical Declination diagrams are shown in Fig. 16-17. Of particular interest to the military user is the relationship of Grid North to Magnetic North, since this defines the relation of Azimuth directions on the map (grid) to an Azimuth obtained with a compass (magnetic). This relationship (the G-M angle), is expressed in degrees and minutes and accompanies the Declination Diagram. Most maps also contain a note for converting from Grid to Magnetic Azimuth and from Magnetic to Grid Azimuth as shown in Figure 16-17. When the note is not given, conversion must be determined based on the Declination diagram.

*NOTE:* Declination Diagrams and G-M Angles vary from map to map. Users should exercise extreme care to insure that the proper conversions from Grid to Magnetic Azimuth or Magnetic to Grid Azimuth are used.

e. *Map Orientation.* Before any map can be used it must be oriented with the ground; that is, when the map is horizontal, its north and south corresponds to north and south on the ground. Two principal methods of map orientation are:

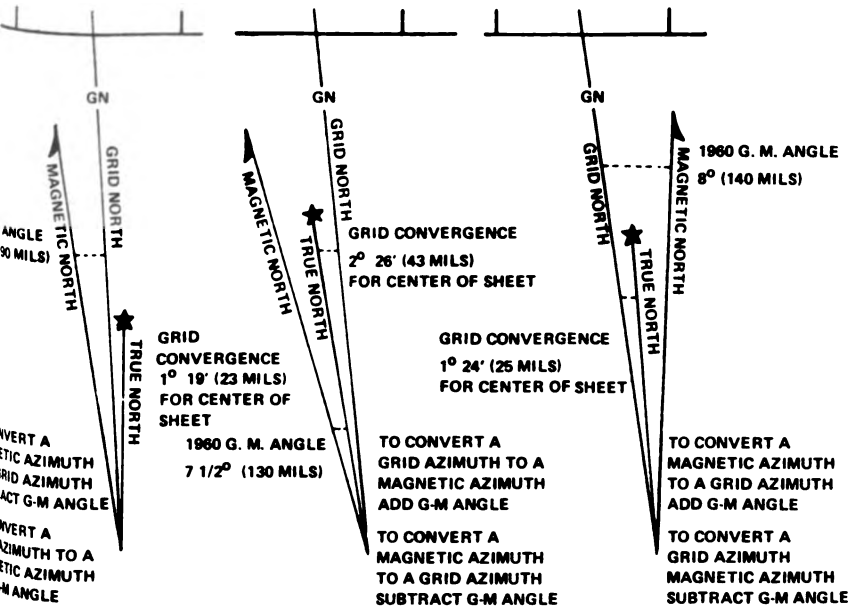


Figure 16-17. Declination diagrams.

(b) Rotate the map and compass until the directions of the black index line and the compass needle match the directions on the declination diagram.

(2) *Terrain Association.*

(a) Carefully examine both the map and the ground to find the linear features (roads, railroads, fences, power lines, etc.) or prominent objects which can be located on both.

(b) Align the feature on the map with the feature on the ground.

*NOTE:* Map Orientation by terrain association results in gross orientation which will usually be sufficiently accurate for land navigation but may not be sufficient for targeting. The use of more than one linear feature or prominent object for orientation will not only preclude reversal of direction but also refine the map-ground orientation.

f. *Scale and Distance (Representative Fraction).*

(1) The scale of a map expresses the ratio of horizontal distance on the map to the corresponding horizontal distance on the ground using the same unit of measurement for both. The representative fraction (RF) is always written with the map distance as: An RF of  $\frac{1}{50,000}$  or  $1/50,000$  means that one (1) unit of measurement on the map equals a corresponding number of like units of measurements (50,000) on the ground.

(2) The ground distance between two points on a map is determined by measuring the distance between the points and multiplying the map measurement by the denominator of the RF.

*Example:* Map distance between two points = 5 units (i.e. 5 in.).

a. The RF of the map is  $1:50,000$ , therefore,

b.  $5 \times 50,000 = 250,000$  units of ground distance (250,000 inches)

c. Further data on finding unknown RF's, ground or map distances, is explained in FM 21-26 and table 16--17.

g. *Contours.* A contour line is a line representing an imaginary line on the ground along which all points are of the same elevation.

(1) Contour lines evenly spaced and wide apart indicate a uniform

MAP DISTANCE	GROUND DISTANCE	REPRESENTATIVE FRACTION (RF)										
		1 25,000	1 50,000	1 75,000	1 100,000	1 200,000	1 250,000	1 500,000	1 1,000,000	1 1,000,000	1 1,000,000	1 1,000,000
ONE INCH	INCHES	25,000	50,000	75,000	100,000	200,000	250,000	500,000	1,000,000	1,000,000	1,000,000	1,000,000
	FEET	2,083	4,167	6,250	8,333	16,667	20,833	41,667	83,333	83,333	83,333	83,333
	YARDS	694	1,389	2,083	2,778	5,555	6,944	13,888	27,776	27,776	27,776	27,776
	METERS	635	1,270	1,905	2,540	5,080	6,350	12,700	25,400	25,400	25,400	25,400
ONE CENTI METER	MILES	0.4	0.8	1.2	1.6	3.2	4	8	16	16	16	16
	KILOMETERS	.64	1.3	1.91	2.54	5.08	6.35	12.7	25.4	25.4	25.4	25.4
	INCHES	9,843	19,685	29,528	39,370	78,740	98,425	196,850	393,700	393,700	393,700	393,700
	FEET	820	1,640	2,460	3,281	6,562	8,202	16,404	32,808	32,808	32,808	32,808
ONE METER	YARDS	273	547	820	1,094	2,187	2,734	5,468	10,936	10,936	10,936	10,936
	METERS	250	500	750	1,000	2,000	2,500	5,000	10,000	10,000	10,000	10,000
	MILES	0.16	0.3	0.5	0.6	1.2	1.5	3	6	6	6	6
	KILOMETERS	.25	.50	.75	1.00	2.00	2.50	5.00	10.00	10.00	10.00	10.00

*h. Slope.* The rate of rise and fall of a ground form is known as its slope. Slope may be expressed in several ways but all depend upon a comparison of vertical distance (VD) to horizontal distance (HD). VD is the difference between the highest and lowest elevations of a slope and is determined from the contour lines. HD is the horizontal ground distance between the highest and lowest elevations of the slope and is measured using the bar scale of the map. The VD and HD must be expressed in the same unit of measurement.

(1) A common expression of slope is as a percent (%) which indicates the number of vertical units of elevation to every hundred units of horizontal distance. Whenever a gradient or percent is used, a plus or minus sign must be given to indicate whether the slope is rising or falling.

(2) Slope may also be expressed in degrees, a unit of angular measure.

Determine the value of  $\frac{VD}{HD}$  in decimal form. This will be the tangent of the slope angle. The slope angle can then be found in table 16-12. The approximate slope angle may be calculated by multiplying the value of  $\frac{VD}{HD}$  by 57.3. This method should only be used for slope angles under 20°.



i. *Aerial Photography As Supplements/Substitutes.*

(1) *General.* Current aerial photography supplements printed maps by showing changes since the map was compiled. Vertical aerial photography (camera aimed straight down) is most often used for this purpose since scale, grid, and orientation are most easily correlated to a map (and therefore the ground). Only an approximate scale of most photographs can be determined, however, for most military applications, this approximate scale is sufficient. Methods of determining scale are:

(a) *Photo-ground comparison method.*

$$\text{Scale (RF)} = \frac{\text{Photo Distance}}{\text{Ground Distance}}$$

(b) *Photo-map comparison method.*

$$\text{Scale (RF)} = \frac{\text{Photo Distance}}{\text{Map Distance}} \times \text{Map Scale (RF)}$$

(c) *Focal length method.*

$$\text{Scale (RF)} = \frac{F (\text{Focal Length})}{H (\text{Flight Altitude}) - h (\text{average ground elevation})}$$

(2) *Point designation grid.* Grids are rarely printed on aerial photography. It is a user responsibility to construct a *world-wide standard* Point Designation Grid on each photo in the following manner (see fig. 16-18).

(a) Hold the photograph so that marginal information, regardless of where it is located, is in the normal reading position; draw straight lines across the photograph joining opposite reference marks (Fiducial marks).

(b) Space grid lines, starting at the center lines, 4 cm. apart, (a distance equal to 1,000 meters at a scale of 1:25,000).

(c) Number each centerline "50" and give numerical values to the remaining horizontal and vertical lines so that they increase to the right and up.

(3) *Photo grid coordinates.* The Point Designated Grid (PDG) is used in the same manner as a map - READ RIGHT-UP. A Grid Coordinate using the Point Designation Grid consists of:

(a) The Letters "PDG".

(b) This mission and photo number (from the photo margin).

(1) *Photo-ground.* Orientation with the ground can be accomplished by compass or terrain association methods as in paragraph 16--14e. Magnetic North is then constructed by aligning the compass with  $0^\circ$  or  $360^\circ$  and drawing a line along the graduated straight edge.

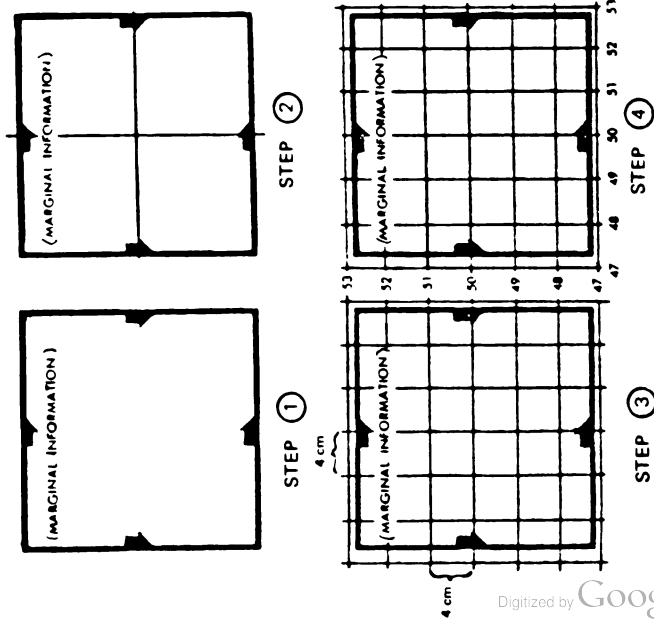


Figure 16-18. Construction of point designation grid.

(2) *Photo-map.*

(a) Carefully examine the photograph and the map to find two features (road junctions, bridges, water towers, etc.) which can be located on both the photo and the map.

(b) Connect the two features on both map and photograph with straight lines.

(c) Using the declination diagram, measure the grid azimuth of the line drawn *on the map* and determine the corresponding magnetic azimuth.

(d) Transfer this magnetic azimuth to the straight line *on the photo*.

(e) Based on this magnetic azimuth construct Magnetic North on the photo.

**16-15. PROJECT MANAGEMENT**

a. *General.* The following technique gives supervisors the ability to plan, schedule and control any engineer project and will point out which areas should be carefully controlled. Detailed references are found in TM 5-333.

b. *Preliminary Planning.*

(1) Receive job directive.

(2) Study directive and accompanying plans and specifications.

(3) Conduct site investigation to determine how the actual site conditions will affect the job. Typical factors are:

- (a) Terrain
- (b) Drainage
- (c) Accessibility
- (d) Soil Conditions
- (e) Existing Facilities
- (f) Natural Resources
- (g) Weather
- (h) Enemy

c. *Task List.*

(1) Break the assigned job into the separate operations or tasks necessary to successfully complete the job. The number and detail of these

## Task

- A. Recon site
- B. Secure and prepare site
- C. Precut caps, sills, and scabs
- D. Precut stringers, decking, and lateral braces
- E. Place abutments
- F. Bridge layout
- G. Construct first trestle bent
- H. Continue trestle bent const.
- I. Place stringers first span
- J. Continue placing stringers
- K. Deck first span
- L. Continue decking
- M. Place curb and riser
- N. Place roadway

d. *Logic.* From the task list determine the essential relationships between the tasks. To accomplish this the following questions should be asked for each task:

- (1) Is this task necessary to begin the project?
- (2) What tasks must be finished before this one begins?
- (3) What tasks may either start or finish at the same time as this one?
- (4) What tasks cannot begin until this is finished?
- (5) Does this task denote project completion?

e. *Estimating.* (Detailed references in TM 5-302 and TM 5-333)

(1) Once the tasks are determined, each task requires an estimate of materials and equipment/manpower needs. Adjust data to reflect appropriate waste and efficiency factors.

(2) Man-hours, man-days, machine-hours or machine days are divided by the men or equipment in your crew to obtain the duration of the task.

## 16-16. CONVERSION FACTORS

See table 16-18.

Table 16-18. Conversion Factors

Multiply	by	to obtain
Acres	43,560	square feet.
acres	4,047	square meters.
acres	$1,562 \times 10^{-3}$	square miles.
acres	5645.38	square varas.
acres	4,840	square yards.
acre-foot	43,560	cubic--feet.
acres	100	square meters.
atmospheres	76.0	cms. of mercury.
atmospheres	29.92	inches of mercury.
atmospheres	33.90	feet of water.
atmospheres	14.70	pounds per sq. inch.
board--feet	144 sq. in. x 1 in.	cubic inches.
British thermal units	0.2520	kilogram--calories.
British thermal units	777.5	foot--pounds.
British thermal units	$2,928 \times 10^{-4}$	kilowatt--hours.
t.u. per min	0.02356	horse--power
t.u. per min	0.01757	kilowatts.
t.u. per min	17.57	watts.
shells	1.244	cubic feet.
stares	1	square meters.
stigrams	0.01	grams.
stiliters	0.01	liters.
timeters	0.3937	inches.
timeters	0.01	meters.
timeters	393.7	mils.
timeters	10	millimeters.
timeters--grams	$10^{-5}$	meter--kilograms.
timeter--grams	$7.233 \times 10^{-5}$	pound--feet.
timeters of mercury	0.01316	atmospheres.
timeters of mercury	0.4461	feet of water.

Table 16 18. Conversion Factors (Con't)

Multiply	by	to obtain
centimeters of mercury	0.1934	pounds per sq. inch.
centimeters per second	0.6	meters per minute.
circular mils	0.7854	square mils.
cord—feet	4 ft. x 4 ft. x 1 ft.	cubic feet.
cords	8 ft. x 4 ft. x 4 ft.	cubic feet.
cubic centimeters	$6.102 \times 10^{-2}$	cubic inches
cubic centimeters	$10^{-6}$	cubic meters.
cubic centimeters	$2.642 \times 10^{-4}$	gallons.
cubic centimeters	$10^{-3}$	liters.
cubic foot	$2.832 \times 10^4$	cubic cms.
cubic foot	1,728	cubic inches.
cubic foot	0.02832	cubic meters.
cubic foot	0.03704	cubic yards.
cubic foot	7.481	gallons.
cubic foot	28.32	liters.
cubic foot per minute	472.0	cubic cms. per sec.
cubic foot per minute	0.1247	gallons per. sec.
cubic foot per minute	0.4720	liters per second
cubic foot per minute	62.4	lbs. of water per min.
cubic inches	16.39	cubic centimeters.
cubic inches	$5.787 \times 10^{-4}$	cubic feet.
cubic inches	0.01732	quarts (liq.).
cubic meters	$10^6$	cubic centimeters.
cubic meters	35.31	cubic feet.
cubic meters	1.308	cubic yards.
cubic meters	264.2	gallons.
cubic yards	27	cubic feet.
cubic yards	0.7646	cubic meters.
cubic yards	202.0	gallons.
cubic yards per minute	0.45	cubic feet per second.
cubic yards per minute	3.367	gallons per second.

Table 16-18. Conversion Factors (Con't)

Multiply	by	to obtain
Decigrams	0.1	grams.
deciliters	0.1	liters.
decimeters	0.1	meters.
degrees (angle)	60	minutes.
degrees (angle)	0.01745	radians.
degrees (angle)	3600	seconds.
dekagrams	10	grams.
dekaliters	10	liters.
dekameters	10	meters.
drams	1.772	grams.
drams	0.0625	ounces.
Ergs	$9.486 \times 10^{-11}$	British thermal units.
Fathoms	6	feet.
feet	0.3048	meters.
feet	.36	varas.
feet	1/3	yards.
feet of water	0.4335	pounds per sq. inch.
feet per minute	0.5080	centimeters per sec.
feet per minute	0.01667	feet per second.
feet per minute	0.01136	miles per hour.
feet per second	1.097	kilometers per hour.
feet per second	0.5921	knots per hour.
feet per second	18.29	meters per minute.
feet per second	0.6818	miles per hour.
feet per 100 feet	1	per cent grade.
foot-grams	$1.286 \times 10^{-3}$	British thermal units.
foot-pounds	$1.356 \times 10^7$	ergs.
foot-pounds	$5.050 \times 10^{-7}$	horse-power-hours.
foot-pounds	$3.241 \times 10^{-4}$	kilogram-calories.
foot-pounds	$3.766 \times 10^{-7}$	kilowatt-hours.
foot-pounds	$3.241 \times 10^{-3}$	kilowatt-hours

<i>multiply</i>	<i>by</i>	<i>to obtain</i>
foot—pounds per minute	$3.241 \times 10^{-4}$	kg—calories per min.
foot—pounds per minute	$2.260 \times 10^{-5}$	kilowatts.
furlongs	40	rods.
Gallons	3785	cubic centimeters.
gallons	0.1337	cubic feet.
gallons	231	cubic inches.
gallons	$3.785 \times 10^{-3}$	cubic meters.
gallons	$4.951 \times 10^{-3}$	cubic yards.
gallons per minute	$2.228 \times 10^{-3}$	cubic feet per second.
gills	0.1183	liters.
grains (troy)	1	grains (av.).
grains (troy)	0.06480	grams.
grains (troy)	0.04167	pennyweights (troy).
grams	980.7	dynes.
grams	15.43	grains (troy).
grams	$10^{-3}$	kilograms.
grams	$10^3$	milligrams.
grams	0.03527	ounces.
grams	0.03215	ounces (troy).
grams	$2.205 \times 10^{-3}$	pounds.
gram—calories	$3.968 \times 10^{-3}$	British thermal units.
gram—centimeters	$2.344 \times 10^{-8}$	kilogram—calories.
gram—centimeters	$10^{-5}$	kilogram—meters.
grams per cm	$5.600 \times 10^{-3}$	pounds per inch.
grams per cu. cm	62.43	pounds per cubic foot.
Hectares	2.471	acres.
hectares	$1.076 \times 10^5$	square feet.
hectograms	100	grams.
hectoliters	100	liters.
hectometers	100	meters.
hectowatts	100	watts.



Table 16-18. Conversion Factors (Con't)

Multiply	by	to obtain
horse-power	42.44	B. t. units per min.
horse-power	33,000	foot-pounds per min.
horse-power	550	foot-pounds per sec.
horse-power	1.014	horse-power (metric).
horse-power	10.70	kg.-calories per min.
horse-power	0.7457	kilowatts.
horse-power	745.7	watts.
inches	2.540	centimeters.
inches	$10^3$	mils.
inches	.03	varas.
inches	0.03342	atmospheres.
inches of mercury	1.133	feet of water.
inches of mercury	70.73	pounds per square ft.
inches of water	0.002458	atmospheres.
inches of water	0.07355	inches of mercury.
inches of water	0.5781	ounces per square in.
inches of water	5.204	pounds per square ft.
inches of water	0.03613	pounds per square in.
Joules	$9.486 \times 10^{-4}$	British thermal units.
joules	$10^7$	ergs.
joules	0.7376	foot-pounds.
joules	$2.390 \times 10^{-4}$	kilogram-calories.
joules	0.1020	kilogram-meters.
joules	$2.778 \times 10^{-4}$	watt-hours.
Kilograms	980,665	dynes.
kilograms	$10^3$	grams.
kilograms	2.2046	pounds.
kilograms	$1.102 \times 10^{-3}$	tons (short).*
kilogram-calories	3.968	British thermal units.
kilogram-calories	3088	foot-pounds.

Table 16. 18. Conversion Factors (Cont.)

Multiply	by	to obtain
kilogram—calories	$1.162 \times 10^{-3}$	kilowatt—hours.
kg.—calories per min	0.06972	kilowatts.
kilogram—meters	$9.302 \times 10^{-3}$	British thermal units.
kilogram—meters	$9.807 \times 10^{-7}$	ergs.
kgs. per cubic meter	$10^{-3}$	grams per cubic cm.
kgs. per cubic meter	0.06243	pounds per cubic foot.
kgs. per square meter	$9.678 \times 10^{-5}$	atmospheres.
kgs. per square meter	$3.281 \times 10^{-3}$	feet of water.
kgs. per square meter	$2.896 \times 10^{-3}$	inches of mercury.
kgs. per square meter	0.2048	pounds per square ft.
kgs. per square meter	$1.422 \times 10^{-3}$	pounds per square in.
kiloliters	$10^3$	liters.
kilometers	$10^5$	centimeters.
kilometers	3281	feet.
kilometers	$10^3$	meters.
kilometers	0.6214	miles.
kilometers per hour	0.5396	knots per hour.
kilowatts	56.92	B.t. units per min.
kilowatts	$4.425 \times 10^4$	foot—pounds per min.
kilowatts	1.341	horse—power.
kilowatts—hour	3415	British thermal units.
kilowatts—hours	$2.655 \times 10^6$	foot—pounds.
knots	1.853	kilometers per hour.
knots	1.152	miles per hour.
Links (engineer's)	12	inches.
links (surveyor's)	7.92	inches.
liters	$10^3$	cubic centimeters.
liters	0.2642	gallons.
liters	1.057	quarts (liq.).
liters per minute	$5.885 \times 10^{-4}$	cubic feet per second.
liters per minute	$4.403 \times 10^{-3}$	gallons per second.

Table 16-18. *Conversion Factors (Con't)*

Multiply	by	to obtain
Meters	100	centimeters.
meters	3.2808	feet.
meters	39.37	inches.
meters	$10^{-3}$	kilometers.
meters	$10^3$	millimeters.
meters	1.0936	yards.
meters	$10^{-6}$	meters.
microns	5280	feet.
miles	1.6093	kilometers.
miles	1760	yards.
miles	1.467	feet per second.
miles per hour	1.6093	kilometers per hour.
miles per hour	0.8684	knots per hour.
milliers	$10^3$	kilograms.
milligrams	$10^{-3}$	grams.
milliliters	$10^{-3}$	liters.
millimeters	0.1	centimeters.
millimeters	0.03937	inches.
millimeters	39.37	mils.
mils	0.002540	centimeters.
mils	$10^{-3}$	inches.
minutes (angle)	$2.909 \times 10^{-4}$	radians.
minutes (angle)	60	seconds (angle).
myriagrams	10	kilograms.
myriameters	10	kilometers.
myriawatts	10	kilowatts.
nautical miles	1.152	miles.
nautical miles	2027	yards.
Ounces	8	drams.
ounces	437.5	grains.
ounces	28.35	grams.

Multiply	by	to obtain
ounces (fluid)	1.805	cubic inches.
ounces (troy)	480	grains (troy).
ounces (troy)	31.10	grams.
ounces (troy)	20	pennyweights (tr.
ounces (troy)	0.08333	pounds (troy).
Perches (masonry)		
pints (dry)	24.75	cubic feet.
pints (liq.)	33.60	cubic inches.
pounds	28.87	cubic inches.
pounds	444.823	dynes.
pounds	453.6	grams.
pounds	16	ounces.
pounds	32.17	pounds.
pound—feet	$1.356 \times 10^7$	centimeter—dyne
pound—feet	13.825	centimeter—gram
pound—feet	0.1383	meter—kilograms
pounds of water	0.01602	cubic feet.
pounds of water	27.68	cubic inches.
pounds of water	0.1198	gallons.
pounds per cubic foot	16.02	kgs. per cubic me
pounds per cubic inch	27.68	grams per cubic c
pounds per foot	1.488	kgs. per meter.
pounds per square foot	0.01602	feet of water.
pounds per square foot	4.882	kgs. per square m
pounds per square inch	0.06804	atmospheres.
pounds per square inch	2.307	feet of water.
pounds per square inch	2.036	inches of mercury
pounds per square inch	703.1	kgs. per square m
pounds per square inch	144	pounds per sq. fo
Quadrants (angle)	90	degrees.
quadrants (angle)	5400	minutes.
quadrants (angle)	1.571	radians.
quarts (dry)	67.20	cubic inches.
quarts (liq.)	57.75	cubic inches.

Table 16--18. Conversion Factors (Con't)

Multiply	by	to obtain
Radians	57.30	degrees.
radians	3438	minutes.
radians	0637	quadrants.
reams	500	sheets.
revolutions	360	degrees.
revolutions	4	quadrants.
revolutions	6.283	radians.
revolutions per minute	6	degrees per second.
revolutions per minute	0.1047	radians per second.
revolutions per minute	0.01667	revolutions per sec.
revs. per min. per min	$1.745 \times 10^{-3}$	rads. per sec. per sec.
revs. per min. per min	0.01667	revs. per min. per sec.
revs. per min. per min	$2.778 \times 10^{-4}$	revs. per sec. per sec.
revolutions per second	360	degrees per second.
revolutions per second	6.283	radians per second.
rods	16.5	feet.
Seconds (angle)	$4.848 \times 10^{-6}$	radians.
square centimeters	0.1550	square inches.
square centimeters	100	square millimeters.
square feet	$2.296 \times 10^{-5}$	acres.
square feet	0.09290	square meters.
square feet	$3.587 \times 10^{-8}$	square miles.
square feet	.1296	square yaras.
square feet	1/9	square yards.
square inches	6.452	square centimeters.
square inches	$6.944 \times 10^{-3}$	square feet.
square kilometers	247.1	acres.
square kilometers	$10.76 \times 10^6$	square feet.
square kilometers	$10^6$	square meters.
square kilometers	0.3861	square miles.
square kilometers	$1.196 \times 10^6$	square yards.
square kilometers	$2.471 \times 10^{-4}$	acres.
square meters	10.764	square yards.

Multiply	by	to obtain
square meters	$3.861 \times 10^{-7}$	square miles.
square meters	1.196	square yards.
square miles	640	acres.
square miles	$27.88 \times 10^6$	square feet.
square miles	2.590	square kilometers.
square miles	3.613,040.45	square varas.
square miles	$3.098 \times 10^6$	square yards.
square yards	$2.066 \times 10^{-4}$	acres.
square yards	9	square feet.
square yards	0.8361	square meters.
square yards	$3.228 \times 10^{-7}$	square miles.
square yards	1.1664	square varas.
steradians	0.1592	hemispheres.
steres	$10^3$	liters.

Temp. (deg. C.) + 273	1	abs. temp. (deg. C.).
temp. (deg. C.) + 17.8	1.8	temp. (deg. Fahr.).
temp. (deg. F.) + 460	1	abs. temp. (deg. F.).
temp. (deg. F.) - 32	5/9	temp. (deg. Cent.).
tons (long)	1016	kilograms.
tons (long)	2240	pounds.
tons (metric)	$10^3$	kilograms.
tons (metric)	2205	pounds.
tons (short)	907.2	kilograms.
tons (short)	2000	pounds.
tons (short) per sq. ft	9765	kgs. per square meter.
tons (short) per sq. ft	13.89	pounds per sq. inch.
tons (short) per sq. in	$1.406 \times 10^6$	kgs. per square meter.
tons (short) per sq. in	2000	pounds per sq. inch.
Varas	2.7777	feet.

Table 16-18. Conversion Factors (Con't)

Multiply	by	to obtain
Watts	0.05692	B.t. units per min.
watts	$10^7$	ergs per second.
watts	44.28	foot-pounds per min.
watts	$1.341 \times 10^{-3}$	horse-power.
watts	$10^2$	kilowatts.
watt-hours	3.415	British thermal units.
weeks	168	hours.
Yards	91.44	centimeters.
yards	3	feet.
yards	36	inches.
yards	0.9144	meters.

NOTE: See FM 5-35 for additional conversion factors.

## 16-17. CONVERSION - ENGLISH UNITS TO METRIC UNITS

See table 16-19.

## 16-18. TIME DISTANCE CONVERSION

See table 16-20.

# Length

	inches	cm	feet	meters	yards	meters	kilo- meters	miles	km	miles	meters	yards	feet	meters	inches	centi- meters																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
1	0.62	1.61	3.22	2.19	1.09	0.91	3.28	0.30	0.39	2.54	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
2	1.24	3.22	4.83	3.28	2.74	1.83	6.56	0.61	0.79	1.18	1.57	1.97	2.36	2.76	3.15	3.54	3.93	4.32	4.71	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
3	1.86	4.83	6.44	4.37	3.66	2.74	9.84	0.91	1.18	1.57	1.97	2.36	2.76	3.15	3.54	3.93	4.32	4.71	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
4	2.49	6.44	8.05	5.47	4.57	3.66	13.12	1.22	1.57	1.97	2.36	2.76	3.15	3.54	3.93	4.32	4.71	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
5	3.11	8.05	9.66	6.56	5.49	4.57	16.40	1.52	1.97	2.36	2.76	3.15	3.54	3.93	4.32	4.71	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
6	3.73	9.66	11.27	7.66	6.40	5.49	19.68	1.83	2.36	2.76	3.15	3.54	3.93	4.32	4.71	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
7	4.35	11.27	12.87	8.75	7.32	6.40	22.97	2.13	2.76	3.15	3.54	3.93	4.32	4.71	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
8	4.97	12.87	14.48	9.84	8.23	7.32	26.25	2.44	3.15	3.54	3.93	4.32	4.71	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
9	5.59	14.48	16.09	10.94	9.14	8.23	29.53	2.74	3.54	3.93	4.32	4.71	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
10	6.21	16.09	17.70	12.03	10.16	9.14	32.81	3.05	3.93	4.32	4.71	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
20	12.43	32.19	35.40	24.06	20.32	18.29	65.62	6.10	7.87	8.75	9.84	10.94	12.03	13.12	14.21	15.30	16.39	17.48	18.57	19.66	20.75	21.84	22.93	24.02	25.11	26.20	27.29	28.38	29.47	30.56	31.65	32.74	33.83	34.92	36.01	37.10	38.19	39.28	40.37	41.46	42.55	43.64	44.73	45.82	46.91	48.00	49.09	50.18	51.27	52.36	53.45	54.54	55.63	56.72	57.81	58.90	59.99	61.08	62.17	63.26	64.35	65.44	66.53	67.62	68.71	69.80	70.89	71.98	73.07	74.16	75.25	76.34	77.43	78.52	79.61	80.70	81.79	82.88	83.97	85.06	86.15	87.24	88.33	89.42	90.51	91.60	92.69	93.78	94.87	95.96	97.05	98.14	99.23	100.32	101.41	102.50	103.59	104.68	105.77	106.86	107.95	109.04	110.13	111.22	112.31	113.40	114.49	115.58	116.67	117.76	118.85	119.94	121.03	122.12	123.21	124.30	125.39	126.48	127.57	128.66	129.75	130.84	131.93	133.02	134.11	135.20	136.29	137.38	138.47	139.56	140.65	141.74	142.83	143.92	145.01	146.10	147.19	148.28	149.37	150.46	151.55	152.64	153.73	154.82	155.91	157.00	158.09	159.18	160.27	161.36	162.45	163.54	164.63	165.72	166.81	167.90	168.99	170.08	171.17	172.26	173.35	174.44	175.53	176.62	177.71	178.80	179.89	180.98	182.07	183.16	184.25	185.34	186.43	187.52	188.61	189.70	190.79	191.88	192.97	194.06	195.15	196.24	197.33	198.42	199.51	200.60	201.69	202.78	203.87	204.96	206.05	207.14	208.23	209.32	210.41	211.50	212.59	213.68	214.77	215.86	216.95	218.04	219.13	220.22	221.31	222.40	223.49	224.58	225.67	226.76	227.85	228.94	230.03	231.12	232.21	233.30	234.39	235.48	236.57	237.66	238.75	239.84	240.93	242.02	243.11	244.20	245.29	246.38	247.47	248.56	249.65	250.74	251.83	252.92	254.01	255.10	256.19	257.28	258.37	259.46	260.55	261.64	262.73	263.82	264.91	266.00	267.09	268.18	269.27	270.36	271.45	272.54	273.63	274.72	275.81	276.90	277.99	279.08	280.17	281.26	282.35	283.44	284.53	285.62	286.71	287.80	288.89	289.98	291.07	292.16	293.25	294.34	295.43	296.52	297.61	298.70	299.79	300.88	301.97	303.06	304.15	305.24	306.33	307.42	308.51	309.60	310.69	311.78	312.87	313.96	315.05	316.14	317.23	318.32	319.41	320.50	321.59	322.68	323.77	324.86	325.95	327.04	328.13	329.22	330.31	331.40	332.49	333.58	334.67	335.76	336.85	337.94	339.03	340.12	341.21	342.30	343.39	344.48	345.57	346.66	347.75	348.84	349.93	351.02	352.11	353.20	354.29	355.38	356.47	357.56	358.65	359.74	360.83	361.92	363.01	364.10	365.19	366.28	367.37	368.46	369.55	370.64	371.73	372.82	373.91	375.00	376.09	377.18	378.27	379.36	380.45	381.54	382.63	383.72	384.81	385.90	386.99	388.08	389.17	390.26	391.35	392.44	393.53	394.62	395.71	396.80	397.89	398.98	400.07	401.16	402.25	403.34	404.43	405.52	406.61	407.70	408.79	409.88	410.97	412.06	413.15	414.24	415.33	416.42	417.51	418.60	419.69	420.78	421.87	422.96	424.05	425.14	426.23	427.32	428.41	429.50	430.59	431.68	432.77	433.86	434.95	436.04	437.13	438.22	439.31	440.40	441.49	442.58	443.67	444.76	445.85	446.94	448.03	449.12	450.21	451.30	452.39	453.48	454.57	455.66	456.75	457.84	458.93	460.02	461.11	462.20	463.29	464.38	465.47	466.56	467.65	468.74	469.83	470.92	472.01	473.10	474.19	475.28	476.37	477.46	478.55	479.64	480.73	481.82	482.91	484.00	485.09	486.18	487.27	488.36	489.45	490.54	491.63	492.72	493.81	494.90	495.99	497.08	498.17	499.26	500.35	501.44	502.53	503.62	504.71	505.80	506.89	507.98	509.07	510.16	511.25	512.34	513.43	514.52	515.61	516.70	517.79	518.88	519.97	521.06	522.15	523.24	524.33	525.42	526.51	527.60	528.69	529.78	530.87	531.96	533.05	534.14	535.23	536.32	537.41	538.50	539.59	540.68	541.77	542.86	543.95	545.04	546.13	547.22	548.31	549.40	550.49	551.58	552.67	553.76	554.85	555.94	557.03	558.12	559.21	560.30	561.39	562.48	563.57	564.66	565.75	566.84	567.93	569.02	570.11	571.20	572.29	573.38	574.47	575.56	576.65	577.74	578.83	579.92	581.01	582.10	583.19	584.28	585.37	586.46	587.55	588.64	589.73	590.82	591.91	593.00	594.09	595.18	596.27	597.36	598.45	599.54	600.63	601.72	602.81	603.90	605.00	606.09	607.18	608.27	609.36	610.45	611.54	612.63	613.72	614.81	615.90	616.99	618.08	619.17	620.26	621.35	622.44	623.53	624.62	625.71	626.80	627.89	628.98	630.07	631.16	632.25	633.34	634.43	635.52	636.61	637.70	638.79	639.88	640.97	642.06	643.15	644.24	645.33	646.42	647.51	648.60	649.69	650.78	651.87	652.96	654.05	655.14	656.23	657.32	658.41	659.50	660.59	661.68	662.77	663.86	664.95	666.04	667.13	668.22	669.31	670.40	671.49	672.58	673.67	674.76	675.85	676.94	678.03	679.12	680.21	681.30	682.39	683.48	684.57	685.66	686.75	687.84	688.93	690.02	691.11	692.20	693.29	694.38	695.47	696.56	697.65	698.74	699.83	700.92	702.01	703.10	704.19	705.28	706.37	707.46	708.55	709.64	710.73	711.82	712.91	714.00	715.09	716.18	717.27	718.36	719.45	720.54	721.63	722.72	723.81	724.90	726.00	727.09	728.18	729.27	730.36	731.45	732.54	733.63	734.72	735.81	736.90	738.00	739.09	740.18	741.27	742.36	743.45	744.54	745.63	746.72	747.81	748.90	750.00	751.09	752.18	753.27	754.36	755.45	756.54	757.63	758.72	759.81	760.90	762.00	763.09	764.18	765.27	766.36	767.45	768.54	769.63	770.72	771.81	772.90	774.00	775.09	776.18	777.27	778.36	779.45	780.54	781.63	782.72	783.81	784.90	786.00	787.09	788.18	789.27	790.36	791.45	792.54	793.63	794.72	795.81	796.90	798.00	799.09	800.18	801.27	802.36	803.45	804.54	805.63	806.72	807.81	808.90	810.00	811.09	812.18	813.27	814.36	815.45	816.54	817.63	818.72	819.81	820.90	822.00	823.09	824.18	825.27	826.36	827.45	828.54	829.63	830.72	831.81	832.90	834.00	835.09	836.18	837.27	838.36	839.45	840.54	841.63	842.72	843.81	844.90	846.00	847.09	848.18	849.27	850.36	851.45	852.54	853.63	854.72	855.81	856.90	858.00	859.09	860.18	861.27	862.36	863.45	864.54	865.63	866.72	867.81	868.90	870.00	871.09	872.18	873.27	874.36	875.45	876.54	877.63	878.72	879.81	880.90	882.00	883.09	884.18	885.27	886.36	887.45	88



Table 16-19 Conversion—English Metric System (Con't)

ONE UNIT (BELOW) ↓ EQUALS →	MM	CM	METERS	KM
MM (MILLIMETERS)	1.	0.1	0.001	0.000,001
CM (CENTIMETERS)	10.	1.	0.01	0.000,01
METERS	1,000.	100.	1.	0.001
KM (KILOMETERS)	1,000,000.	100,000.	1,000.	1.

ONE UNIT (BELOW) ↓ EQUALS →	GM	KG	METRIC TON
GM (GRAM)	1.	0.001	0.000,001
KG (KILOGRAMS)	1,000.	1.	0.001
METRIC TON	1,000,000.	1,000.	1.

## UNITS OF CENTIMETERS

CM	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.10
INCH	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.31	0.35	0.39

## FRACTIONS OF AN INCH

INCH	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
CM	0.16	0.32	0.48	0.64	0.79	0.95	1.11	1.27

INCH	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
CM	1.43	1.59	1.75	1.91	2.06	2.22	2.38	2.54

WEIGHT

	ounces	grams	pounds	kg	short ton	metric ton	short ton	pounds	kilograms	ounces	grams
1							↓				
2							↓				
3							↓				
4							↓				
5							↓				
6							↓				
7							↓				
8							↓				
9							↓				
10							↓				
20							↓				
30							↓				
40							↓				
50							↓				
60							↓				
70							↓				
80							↓				
90							↓				
100							↓				

Example: 28 pounds = 9.07 kg + 3.63 kg = 12.70 kg

Table 16-19. Conversion-English Metric Systems (Con't)

<u><u>VOLUME</u></u>									
cu. meters		cu. ft → cu. yd		cu. ft → cu.		cu. ft → cu. yd		cu. ft → cu. yd	
cu. yd		cu. ft → cu.		meters		meters		meters	
cu. ft → cu. yd		meters		meters		meters		meters	
1	0.037	0.028	27.0	0.76	35.3	1.31	35.3	1.31	1.31
2	0.074	0.057	54.0	1.53	70.6	2.62	70.6	2.62	2.62
[3]	0.111	0.085	[81.0]	2.29	105.9	3.92	105.9	3.92	3.92
4	0.148	0.113	108.0	3.06	141.3	5.23	141.3	5.23	5.23
5	0.185	0.142	135.0	3.82	176.6	6.54	176.6	6.54	6.54
6	0.212	0.170	162.0	4.59	211.9	7.85	211.9	7.85	7.85
7	0.259	0.198	189.0	5.35	247.2	9.16	247.2	9.16	9.16
8	0.296	0.227	216.0	6.12	282.5	10.46	282.5	10.46	10.46
9	0.333	0.255	243.0	6.88	317.8	11.77	317.8	11.77	11.77
10	0.370	0.283	270.0	7.65	353.1	13.07	353.1	13.07	13.07
20	0.741	0.566	540.0	15.29	706.3	26.16	706.3	26.16	26.16
30	1.111	0.850	810.0	22.94	1059.4	39.24	1059.4	39.24	39.24
40	1.481	1.133	1080.0	30.58	1412.6	52.32	1412.6	52.32	52.32
50	1.852	1.416	1350.0	38.23	1765.7	65.40	1765.7	65.40	65.40
60	2.222	1.700	1620.0	45.87	2118.9	78.48	2118.9	78.48	78.48
70	2.592	1.982	1890.0	53.52	2472.0	91.56	2472.0	91.56	91.56
80	2.962	2.265	2160.0	61.16	2825.2	104.63	2825.2	104.63	104.63
90	3.333	2.548	2430.0	68.81	3178.3	117.71	3178.3	117.71	117.71
100	3.703	2.832	2700.0	76.46	3531.4	130.79	3531.4	130.79	130.79

Example: 3 cu. yd = 81.0 cu ft

Table 16-20. Time Distance Conversion

Miles per hour	Knots	Feet per Second	Kilometers per hour	Meters per Second
1	0.8684	1.4667	1.609	0.447
2	1.74	2.93	3.22	0.894
3	2.61	4.40	4.83	1.34
4	3.47	5.87	6.44	1.79
5	4.34	7.33	8.05	2.24
6	5.21	8.80	9.66	2.68
7	6.08	10.27	11.27	3.13
8	6.95	11.73	12.87	3.58
9	7.82	13.20	14.48	4.02
10	8.68	14.67	16.09	4.47
15	13.03	22.00	24.14	6.71
20	17.37	29.33	32.19	8.94
25	21.71	36.67	40.23	11.18
30	26.05	44.00	48.28	13.41
35	30.39	51.33	56.33	15.64
40	34.74	58.67	64.37	17.88
45	39.08	66.00	72.42	20.12
50	43.42	73.33	80.47	22.35
55	47.76	80.67	88.51	24.59
60	52.10	88.00	96.56	26.82
65	56.45	95.33	104.61	29.06
70	60.79	102.67	112.65	31.29
75	65.13	110.00	120.70	33.53
100	86.84	146.67	160.94	44.70

## APPENDIX A

### REFERENCES

#### A-1. ARMY REGULATIONS

AR 310-25	Dictionary of United States Army Terms
AR 310-50	Authorized Abbreviations and Brevity Codes

#### A-2. DEPARTMENT OF THE ARMY PAMPHLETS

DA Pam 108-1	Index of Army Motion Pictures and Related Audio-Visual Aids.
DA Pam 310 Series	Military Publications Indexes (as applicable)
DA Pam 350-19	Training, Signal Security Instructional Packet

#### A-3. FIELD MANUALS

FM 3-8	Chemical Reference Handbook
FM 5-1	Engineer Troop Organizations and Operations
FM 5-13	The Engineer Soldier's Handbook
FM 5-15	Field Fortifications
FM 5-20	Camouflage
FM 2-25	Explosives and Demolitions
FM 5-30	Engineer Intelligence
FM 5-31	Boobytraps
FM 5-35	Engineer's Reference and Logistical Data
FM 5-36	Route Reconnaissance and Classification
FM 10-13	Supply and Service Reference Data

FM 21-10	Techniques of Military Instruction
FM 21-10	Field Hygiene and Sanitation
FM 21-26	Map Reading
FM 21-30	Military Symbols
FM 21-31	Topographic Symbols
FM 21-41	Soldier's Handbook for Defense Against Chemical and Biological Operations and Nuclear Warfare
FM 21-60	Visual Signals
FM 21-76	Survival, Evasion and Escape
FM 24-1	Tactical Communications Doctrine
FM 24-18	Field Radio Techniques
FM 30-5	Combat Intelligence
FM 30-10	Denial Operations and Barriers
FM 31-60	River-Crossing Operations
FM 31-70	Basic Cold Weather Manual
FM 32-5	Signal Security
FM 32-6	Signal Security Techniques
FM 55-15	Transportation Reference Data
FM 101-10-1	Staff Officers' Field Manual

#### A-4. TECHNICAL MANUALS

TM 3-220	CBR Decontamination
TM 3-366	Flame Fuels
TM 5-200	Camouflage Materials
TM 5-210	Military Floating Bridge Equipment
TM 5-216	Armored Floating Bridge Equipment
TM 5-220	Passage of Obstacles Other Than Minefields
TM 5-232	Elements of Surveying
TM 5-233	Construction Surveying
TM 5-258	Pile Construction
TM 5-270	Cableways, Tramways, and Suspension Bridges

TM 5-337	Paving and Surfacing Operations
TM 5-342	Logging and Sawmill Operation
TM 5-349	Artic Construction
TM 5-461	Engineer Handtools
TM 5-617	Roofing, Repairs and Utilities
TM 5-618	Paints and Protective Coating
TM 5-624	Roads, Runways, and Miscellaneous Pavements; Repairs and Utilities
TM 5-700	Field Water Supply
TM 5-725	Rigging
TM 5-742	Concrete and Masonry
TM 5-766	Electrical Power Generation in the Field
TM 5-277	Bailey Bridge
TM 5-280	Foreign Mine Warfare Equipment
TM 5-297	Well Drilling Operations
TM 5-302	Construction in the Theater of Operations
TM 5-311	Military Protective Construction (Nuclear Warfare and Chemical and Biological Operations)
TM 5-312	Military Fixed Bridges
TM 5-315	Firefighting and Rescue Operations in Theaters of Operations
TM 5-330	Planning and Design of Roads, Airbases, and Heliports in the Theater of Operations
TM 5-330-1	Hasty Revetments for Parked Aircraft
TM 5-331A	Earthmoving, Compaction, Grading and Ditching Equipment
TM 5-331B	Lifting, Loading, and Hauling Equipment
TM 5-331C	Rock Crushers, Air Compressors, and Pneumatic Tools
TM 5-331D	Asphalt and Concrete Equipment
TM 5-331E	Engineer Special Purpose and Expedient Equipment
TM 5-332	Pits and Quarries
TM 5-333	Construction Management

TM 5-6665-202-15  
 TM 5-6665-293-13  
 TM 9-1300-214  
 TM 9-1375-200

Detecting Set, Mine, (AN/PSS-11)  
 Detecting Set, Mine (AN/PRS-7)  
 Military Explosives  
 Demolition Materials

## A-5. TRAINING CIRCULARS

TC 6-135

Fire for Effect, How to be Your Forward  
 Observer

## A-6. NATO AGREEMENTS (STANAGS)

2001

Marking Lanes through Minefields

2002

Marking of Contaminated or Dangerous  
 Areas

2010

Bridge Classification Markings

2012

Military Route Signing

2015

Route Classification

2019

Military Symbols

2021

Computation of Bridge, Raft, and Vehicle  
 Classifications

2027

Marking of Military Vehicles

2036

Land Minefield Laying, Recording,  
 Reporting and Marking Procedures

2096

Reporting Engineer Information in the  
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2136

Minimum Standards of Water Potability

2269

MGD - Engineer Resources



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**FM 5-34**

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